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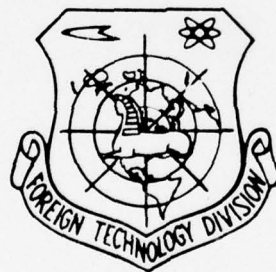
FOREIGN TECHNOLOGY DIVISION



LOGARITHMIC AMPLIFIERS

by

V. M. Volkov



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LOGARITHMIC AMPLIFIERS

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	<i>A a</i>	A, a	Р р	<i>P p</i>	R, r
Б б	<i>B b</i>	B, b	С с	<i>C c</i>	S, s
В в	<i>V v</i>	V, v	Т т	<i>T t</i>	T, t
Г г	<i>G g</i>	G, g	У у	<i>U u</i>	U, u
Д д	<i>D d</i>	D, d	Ф ф	<i>F f</i>	F, f
Е е	<i>E e</i>	Ye, ye; E, e*	Х х	<i>Kh kh</i>	Kh, kh
Ж ж	<i>Zh zh</i>	Zh, zh	Ц ц	<i>Ts ts</i>	Ts, ts
З з	<i>Z z</i>	Z, z	Ч ч	<i>Ch ch</i>	Ch, ch
И и	<i>I i</i>	I, i	Ш ш	<i>Sh sh</i>	Sh, sh
Й й	<i>Y y</i>	Y, y	Щ щ	<i>Shch shch</i>	Shch, shch
К к	<i>K k</i>	K, k	Ъ ъ	<i>"</i>	"
Л л	<i>L l</i>	L, l	Ы ы	<i>Y y</i>	Y, y
М м	<i>M m</i>	M, m	Ь ь	<i>'</i>	'
Н н	<i>N n</i>	N, n	Э э	<i>E e</i>	E, e
О о	<i>O o</i>	O, o	Ю ю	<i>Yu yu</i>	Yu, yu
П п	<i>P p</i>	P, p	Я я	<i>Ya ya</i>	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
 When written as ё in Russian, transliterate as yë or ë.
 The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	A	α	α	Nu	N	ν
Beta	B	β		Xi	Ξ	ξ
Gamma	Γ	γ		Omicron	Ο	ο
Delta	Δ	δ		Pi	Π	π
Epsilon	E	ε	ε	Rho	Ρ	ρ ϑ
Zeta	Z	ζ		Sigma	Σ	σ ς
Eta	H	η		Tau	T	τ
Theta	Θ	θ	θ	Upsilon	Υ	υ
Iota	I	ι		Phi	Φ	φ φ
Kappa	K	κ	κ x	Chi	Χ	χ
Lambda	Λ	λ		Psi	Ψ	ψ
Mu	M	μ		Omega	Ω	ω

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	\sin^{-1}
arc cos	\cos^{-1}
arc tg	\tan^{-1}
arc ctg	\cot^{-1}
arc sec	\sec^{-1}
arc cosec	\csc^{-1}
arc sh	\sinh^{-1}
arc ch	\cosh^{-1}
arc th	\tanh^{-1}
arc cth	\coth^{-1}
arc sch	sech^{-1}
arc csch	csch^{-1}
<hr/>	
rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

Logarithmic amplifiers.

V. M. Volkov.

Pages 1-244.

Page 2.

In the book are presented the theory and the calculation of selective and aperiodic logarithmic amplifiers, are examined the possible methods of obtaining logarithmic amplitude characteristic, transient processes in aperiodic and selective logarithmic amplifiers, the field of their application/use, and are also given practical diagrams.

The book is intended for technical personnel in the field of radio electronics, who are occupied by development and the

construction of logarithmic amplifiers, and also for the students of radio engineering VUZ [- Institute of Higher Education] and technical schools.

Page 3.

Preface.

Our country, which is the native land of radio, provides the all possible development of this most important branch of science and engineering and its wide introduction into national economy. The solution to the majestic problem of developing of the material and technical base of Communist society in our country is unthinkable without the development of radio electronics. For the automation of productions, provided for by program, it is necessary to solve a number of scientific problems in electronics and to create qualitatively new electronic equipment.

Amplifiers with by logarithmic amplitude characteristic recently all more are applied in the different fields of radio electronics, automation and in the measuring technique.

The idea of obtaining and the practical implementation of equipment/devices with logarithmic amplitude characteristic familiar to the Soviet scientists. Thus, for instance, in the institute of radio receiving equipment the acousticians (IRPA) in 1937 was developed logarithmic amplifier-voltmeter for the record of frequency

receiver responses [21]. The principle, used in this equipment/device for obtaining logarithmic amplitude characteristic, is based on the use of amplifier tubes with the exponential form of static characteristic and the application/use of automatic gain control (AGC). Approximately in the same period abroad, appeared [44], in which was described the logarithmic direct-current amplifier with dynamic range 50 dB. Logarithmic amplitude characteristic in this amplifier was obtained also as a result of application/use AGC.

Page 4.

In postwar period in the Soviet and foreign press, appeared a series of the works of descriptive and theoretical character, dedicated to the analysis of logarithmic amplifiers (LAX). In some of these sources [15], [33] are erroneous theoretical propositions and conclusion/derivations relative to the work of logarithmic amplifiers. In this book the author sets forth the possible methods of obtaining logarithmic amplitude characteristic in the amplifiers of any type, special feature/peculiarity of transient processes in logarithmic amplifiers and gives practical diagrams and examples of the calculation of logarithmic amplifiers.

The material, presented in the book, largely is original.

The author expresses the sincere appreciation of the Dr. of tekhn, sciences, prof. To N. F. Vollerner for large by aid, shown the

author during the development of number of questions concerning logarithmic amplifiers, and for his valuable councils and the observations, made during the review of the book. Simultaneously the author thanks the comrades for the consistent scientific work: the Cand. of tekhn, sciences of A. M. Volkov, eng. V. V. Sidorenko, B. P. Khizhinskogo, by V. F. Andriyenko and I. I. Gusachenko, that took part in the development of number of questions and the setting of experiment.

Observations and the wishes about this book request to guide to: Kiev, 4, Puskinskaya, 28, the State Technical Press of UkrSSR [- Ukrainian].

Author.

Page 5.

Chapter One ~~is~~

LOGARITHMIC AMPLIFIERS.

Logarithmic amplifiers (LAX) widely are applied at present in the different fields of science and engineering, beginning from radar and terminating with the biology. In each concrete/specific/actual case the logarithmic amplifier must satisfy the completely definite requirements and have appropriate qualitative indices. Before passing

to the examination of the possible fields of application of logarithmic amplifiers, it is expedient to examine their fundamental qualitative indices.

§1. Fundamental qualitative indices of logarithmic amplifiers.

In logarithmic amplifier occurs the logarithmic dependence between the output U_{out} and the input U_{in} as voltage/stresses.

FOOTNOTE 1. For the target/purpose of simplification in the writing of mathematical expressions, index m , which designates the amplitude of stress, is lowered. Therefore for selective amplifiers under U , it is necessary to understand the amplitude of stress. ENDFOOTNOTE.

Consequently, the logarithmic amplifier is the nonlinear amplifier at whose amplification factor decreases in the determined law during an increase in the input voltage.

The logarithmic amplifier is characterized by following fundamental qualitative indices:

1) input U_{inH} and output U_{outH} by the voltages with which begins the LAX of amplifier (Fig. 1);

2) input U_{inK} and output U_{outK} by the voltages, with which terminates the LAX of amplifier;

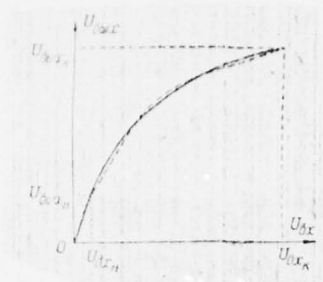


Fig. 1. Amplitude characteristic of the logarithmic amplifier:
— raschetvaya; ---- experimental.

3) by dynamic range on the input voltage

$$D = \frac{U_{BXK}}{U_{BXH}} \quad (1.1)$$

or in relative logarithmic units - decibells and the nepers

$$\begin{aligned} D_{(dB)} &= 20 \lg D, \\ D_{(nep)} &= \ln D; \end{aligned} \quad (1.2)$$

4) by dynamic range on the output voltage

$$D_{VLK} = \frac{U_{VLXK}}{U_{VLXH}} \quad (1.3)$$

or in decibells and the nepers

$$\begin{aligned} D_{VLX(DB)} &= 20 \lg D_{VLX}, \\ D_{VLX(nep)} &= \ln D_{VLX}; \end{aligned}$$

5) by the contraction coefficient of the amplified stress

$$C = \frac{D}{D_{VLX}}; \quad (1.4)$$

6) by the maximum factor of amplification K_0 of the work of amplifier in linear conditions, i.e., during the fulfillment of the inequality

$$U_{BX} \leq U_{BXH};$$

7) by the range of the amplified frequencies from F_{MH} to F_{MK} for aperiodic amplifiers or by passband ΔF and by resonance frequency f_0 for selective amplifiers (determination of the cut-off frequencies of the F_{MK} and F_{MH} is given in work [3]) of work in linear mode/conditions;

8) by the accuracy of the LAX of amplifier, which shows the

maximum relative deflection to all dianamicheskoy range D of the experimental characteristic of amplifier (dashed curve in Fig. 1) of the calculated accurately logarithmic (unbroken curve in Fig. 1)

$$\delta = \frac{U_{\text{BIX}} - U_{\text{BIXP}}}{U_{\text{BIXP}}}, \quad (1-5)$$

where U_{BIX} - the progressive output voltage with experimental by LAX; U_{BIXP} are the progressive output voltage with calculated by LAX;

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9) by the stability or the recurrence of the LAX, which characterizes the possibility of the series production of logarithmic amplifiers with the identical parameters.

Let us examine the amplitude characteristic of amplifier, depicted on Fig. 1, and let us find for it analytical expression. From practice it is known that any nonlinear amplifier with sufficiently small input voltage works in linear conditions, and during an increase in the input voltage it passes to nonlinear operating mode. Let us assume that the nonlinear amplifier works in linear conditions and uslivaet signals with the maximum factor of amplification K_0 of the values of input voltage from 0 of up to

U_{BXH} . The amplitude characteristic of amplifier in this case is described by the equation

$$U_{\text{BIX}} = K_0 U_{\text{BX}}. \quad (1-6)$$

In this case, the differential factor of amplification of the $K_{\text{диф}}$, which is numerically equal to the ratio infinitesimal increment in the output voltage to infinitesimal increment in the input voltage, is maximum and is constant value

$$K_{\text{диф.лин}} = \frac{dU_{\text{вых}}}{dU_{\text{вх}}} = K_0. \quad (1-7)$$

At the values of input voltage from $U_{\text{вхн}}$ to $U_{\text{вхк}}$ the amplifier works in the logarithmic mode/conditions by which the differential amplification factor - value variable, is equal to

$$\frac{dU_{\text{вых}}}{dU_{\text{вх}}} = \frac{M}{U_{\text{вх}}}, \quad (1-8)$$

where to M - proportionality factor.

As a result of integration of expression (1-8) we obtain the mathematical equation of the logarithmic dependence of output voltage from the input

$$U_{\text{вых}} = M \ln U_{\text{вх}} + C. \quad (1-9)$$

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In order that the amplitude characteristic of amplifier would not have sharp fractures and would have smooth transition, at any transition point of it of two adjacent sections, must be fulfilled the following conditions:

1) the equality of first-order derivatives or, that the same, the equality of the differential factors of amplification infinitesimal adjacent sections:

2) the equality of the ordinates of adjacent sections.

For the determination of integration constant C in uravneii (I-9) we utilize these conditions for the transition point of amplitude characteristic from linear section to logarithmic. On the basis of the first condition, with approach to transition point from the side of the linear section of characteristic we have

$$\frac{dU_{\text{lin}}}{dU_{\text{bxH}}} = K_0, \quad (I-10)$$

with approach from another side for this point it is fulfilled the equality

$$\frac{dU_{\text{bxH}}}{dU_{\text{lin}}} = \frac{M}{U_{\text{bxH}}}. \quad (I-11)$$

On the basis of the second condition, respectively we have:

$$U_{\text{lin}} = K_0 U_{\text{bxH}}; \quad (I-12)$$

$$U_{\text{bxH}} = M \ln U_{\text{bxH}} + B. \quad (I-13)$$

From expressions (I-10) - (I-13) we find:

$$M = U_{\text{bxH}} K_0;$$

$$B = U_{\text{bxH}} K_0 (1 - \ln U_{\text{bxH}}).$$

After substituting values of M and B into equation (I-9), we will obtain the resultant analytical expression of the amplitude

characteristic of amplifier in work in the logarithmic mode/conditions

$$U_{\text{out}} = K_0 U_{\text{in}} \left(\ln \frac{U_{\text{ex}}}{U_{\text{in}}} + 1 \right) \quad (1.14)$$

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In the case of n-cascade amplifier the maximum factor of amplification

$$K_0 = K_1^n \quad (1.15)$$

where n is a number of cascade/stages; K_1 - the maximum factor of amplification of one cascade/stage of work in linear conditions.

Equation (1-14) is correct during the logarithmic operation of input voltage according to the law of natural logarithm with foundation $N = e = 2.72$. In order that equation (1-14) would be correct for any base of logarithm, it is necessary to introduce conversion factor

$$a = \frac{1}{\ln N} \quad (1.16)$$

The coefficient a characterizes slope/inclination the LAX of amplifier and determines the differential amplification factor of its work in logarithmic mode/conditions.

Taking into account coefficient of a, the expression (1-14) takes the form

$$U_{\text{blx}} = K_0 U_{\text{bxH}} \left(a \ln \frac{U_{\text{bx}}}{U_{\text{bxH}}} + 1 \right). \quad (1-17)$$

At rated value of the dynamic range D of amplifier according to formula (1-17) it is possible to opedelit a series of qualitative indices. Specifically, the dynamic range of amplifier in the output voltage

$$D_{\text{blx}} = \frac{U_{\text{blxK}}}{U_{\text{blxH}}} = \frac{K_0 U_{\text{bxH}} (a \ln D + 1)}{K_0 U_{\text{bxK}}} = a \ln D + 1 \quad (1-18)$$

and contraction coefficient

$$C = \frac{D}{D_{\text{blx}}} = \frac{D}{a \ln D + 1}. \quad (1-19)$$

From expression (1-18) it is evident that at rated value of the dynamic range D in input voltage the coefficient a uniquely determines the dynamic range of amplifier according to output voltage. And vice versa, coefficient a can be cpedelen in terms of known values of D and D_{blx}

$$a = \frac{D_{\text{blx}} - 1}{\ln D}. \quad (1-20)$$

During the introduction of relative voltages, the record of the aplitudnoy characteristic of amplifier (1-17) becomes more common/general/total and simpler

$$Z = a \ln X + 1, \quad (1-21)$$

where $X = \frac{U_{\text{bx}}}{U_{\text{bxH}}}$ - relative input voltage; $Z = \frac{U_{\text{blx}}}{U_{\text{blxH}}}$ are relative output voltage.

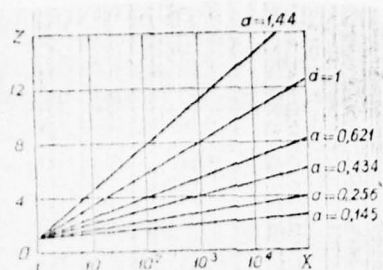


Fig. 2. Given amplitude characteristics of multistage logarithmic amplifier on semilogarithmic scale.

The amplitude characteristic of amplifier $Z = f(X)$, expressed in relative voltages, let us agree to call the given amplitude characteristic. Figure 2 on polulogarimicheskoy scale depicts the given LAX of amplifier for the different values of coefficient of a . Dynamic range on input voltage is accepted by $D = 10^5$.

It should be noted that the LAX of amplifier on the semilogarithmic scale when along the axis of abscissas is taken logarithmic scale, and along the axis of ordinates - linear, it takes the form of straight line. The characteristics, given in Fig. 2, are designed according to formula (I-21).

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§2. Application/use of logarithmic amplifiers in the receivers of radar stations ¹.

FOOTNOTE ¹. Paragraph is written on the basis of the sources of foreign literature [33], [35]. ENDFOOTNOTE.

The saturation of the output stages of receiver under the influence on its input of considerable in value signals and interferences is one of the limiting factors in radar equipment/devices of different designation/purpose. For search radars by the reason for the overloading of priyenika, are the interferences, which are the reflections of signals from mountains, forests, sea surface and cloudbursts. If interferences have an amplitude, greater than signal amplitude, reflected from object, then to reveal/detect it without the application/use of special methods of the isolation of signals out of interferences difficultly or is generally impossible. In many instances of interference, they have an amplitude lesser than

the signal amplitude, but the latter is lost as a result of the saturation of receiver or indicator by interferences.

With low input signals the characteristic of radar receiver is subordinated to quadratic or linear law. In this case, the receiver completely is impregnated by the signals whose value reaches the order of several volts on the control electrode of the last/latter tube of IF amplifier (UpCh). For radars of the long-range detection which utilize an ultimate sensitivity of receiver, this corresponds to signals, approximately 20-30 times exceeding the effective value of the voltage of inherent noise. The indicator of priyenika is impregnated by men'shmi by the signals, which reach the approximately twenty-fold value of effective noise voltage, if indicator with amplitude indication, and dual value, if indicator with brightness indication. It is necessary that radar stations be equipped by the systems which regulate the amplification of receiver, they prevent it from saturation and instantly they wear/operate.

The receiver with logarithmic amplitude characteristic provides momentary effect, it does not lose sensitivity after the reception of powerful signals and has the inherent noise at output/yield, which insignificantly exceed the noises of usual radar receiver. If changes in the disturbing voltage have a character of changes in the noise voltage of receiver (interference, modulated by noises, passive jamming and interferences, reflected from heterogeneities), then the voltage of the interfering signals can be pressed to the noise level

of receiver independent of the intensity of the interfering signals. These properties make logarithmic receiver with very valuable equipment/device in search radars and the automatic tracking of object.

It is known that the output potential of receiver in the absence of signal not is equal to zero, but it oscillates irregularly about zero. On scope, these oscillation/vibrations create the typical noise pattern, caused by the tube noises and network elements (the inherent noise of receiver). Per cycle of the running through of ray/beam on screen, which corresponds to range scanning, the inherent noise of receiver are characterized approximately by the constant value of root-mean-square amplitude σ .

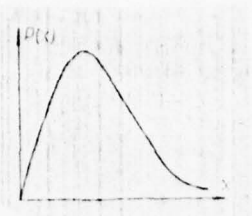


Fig. 3. Amplitude distribution according to the law of Rayleigh.

In this case, the distribution envelope of amplitudes obeys the law of Rayleigh (Fig. 3)

$$P(x) = \frac{2x}{\sigma^2} e^{-\frac{x^2}{\sigma^2}} dx \text{ для } x > 0, \quad (1.22)$$

where x is an instantaneous value of amplitude; $P(x)$ - probability density or the one-dimensional differential distribution function envelope of the amplitudes of the noise voltage of receiver.

The signals, reflected from heterogeneities, create on the output/output of receiver the voltage, similar in form to the voltage of the inherent noise of receiver.

During the fulfillment of the equality

$$t_n = \tau,$$

where $\tau = 1/\Delta F$ - time of the correlation of receiver; ΔF - the passband of receiver; t_n - the pulse duration of signal, the only difference between the inherent noise of receiver and the signals, reflected from heterogeneities, it entails a decrease in the intensity of the latter in proportion to the increase in the range. Consequently, σ interferences - value is variable.

It is necessary to note that the law of the distribution envelope of the amplitudes of the interferences, reflected from heterogeneities, the nearer to Rayleigh law, the greater the duration of sounding pulse and the wider the radiation pattern of the antenna of radar station.

Let us examine the properties of logarithmic receiver. The communication/connection between the output $y = U_{\text{out}}$ and the input $x = U_{\text{in}}$ by the voltages in logarithmic receiver according to formula (I-17) it is possible to record in the following form:

$$y = R \ln Sx, \quad (I-23)$$

where $R = aK_0 U_{\text{BXH}}$ and $S = e^{\frac{1}{a} U_{\text{BXH}}^{-1}}$ are constants of amplifier.

During the determination of the properties of logarithmic receiver, let us assume that the inherent noise of receiver and the signals, reflected from heterogeneities, obey the law of Rayleigh distribution.

Page 13.

For the solution to stated problem expediently to introduce the new variable

$$u = \frac{x^2}{\sigma^2} \quad \text{npn } u > 0. \quad (I-24)$$

Then the law of distribution (I-22) can be presented in the form

$$P(u) du = e^{-u} du \quad \text{npn } u > 0. \quad (I-25)$$

with (I)

The equation (I-23), recorded in the form

$$y = \frac{R}{2} \ln(S^2 x^2),$$

after the substitution of value x of uravneiia (I-24) assumes the form

$$y = \frac{R}{2} [\ln(S^2 \sigma^2) + \ln u].$$

If the input of receiver affects random signal (interference) with amplitude distribution $P(u) du$, then the probability distribution of the output signal $P(y) dy$ has the following parameters.

Average value of interference at the output/yield of the receiver

$$m(y) = \int_0^{\infty} \frac{R}{2} [\ln(S^2 \sigma^2) + \ln u] P(u) du = \\ = \frac{R}{2} \left\{ \ln(S^2 \sigma^2) + \int_0^{\infty} (\ln u) P(u) du \right\},$$

since $\int_0^{\infty} P(u) du = 1$ regarding probability.

The RMS value of interference at the output/yield of the receiver

$$m(y^2) = \int_0^{\infty} \frac{R^2}{4} [\ln(S^2 \sigma^2) + \ln u]^2 P(u) du = \\ = \frac{R^2}{4} \left\{ [\ln(S^2 \sigma^2)]^2 + 2 \ln(S^2 \sigma^2) \int_0^{\infty} (\ln u) P(u) du + \right. \\ \left. + \int_0^{\infty} (\ln u)^2 P(u) du \right\},$$

Page 14.

Dispersion of interference at the output/yield of the receiver

$$M(y) = m(y^2) - [m(y)]^2 = \\ = \frac{R^2}{4} \left\{ \int_0^{\infty} (\ln u)^2 P(u) du - \left[\int_0^{\infty} (\ln u) P(u) du \right]^2 \right\}. \quad (1.26)$$

Substituting in expression (I-26) the law of distribution (8.25), we have

$$M(y) = \frac{R^2}{4} \left\{ \int_0^{\infty} (\ln u)^2 e^{-u} du - \left[\int_0^{\infty} (\ln u) e^{-u} du \right]^2 \right\}. \quad (I-27)$$

The entering the equation (I-27) integrals can be found in the tables of laplasovkykh converters. Final solution to equation (I-27)

$$M(y) = \frac{R^2 \pi^2}{24}. \quad (I-28)$$

Work [35] shows that the dispersion of interference at the output/yield of the real logarithmic receiver

$$M(y)_p = \frac{R}{4} \left(\frac{\pi^2}{6} - A \right), \quad (I-29)$$

where $A = \frac{\gamma}{S^2 \sigma^2} \left(1 + \ln S^2 \sigma^2 - \gamma + \frac{1}{2 S^2 \sigma^2} \right)$ is correction factor;
 $\gamma \approx 0.577$ - is Euler's constant.

If receiver has the logarithmic characteristic, which begins from level on 20 dB lower than RMS value of inherent noise, it is possible to accept $S\sigma = 10$. The correction factor in this case is equal to 0.1. Noise signals, reflected from heterogeneities, can exceed the RMS value of their own shmov of receiver to 80 dB. In this case value $\sigma^2 = 10^8$ and correction factor A considerably decrease. Consequently, during a change in the interference level, reflected from heterogeneities, in the range 100 dB the value of $M(y)_p$ is virtually constant and is determined by expression (I-28).

Thus, if the input of logarithmic receiver it affects interferences with Rayleigh amplitude distribution, then the standard

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PAGE

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deviation of interference from the average value at the output/yield of receiver is the constant value, which does not depend on the RMS value of input signal.

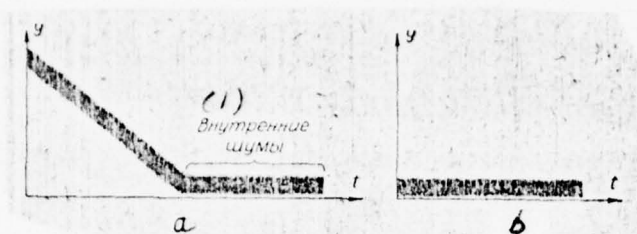


Fig. 4. Output potential of the logarithmic receiver: a) without the differentiating circuit; b) with the differentiating circuit.

Key: (1). Internally-produced noise.

In this case, the RMS value of the fluctuations of the interference at the output/yield of the receiver

$$\sigma_{\text{nom}} = \sqrt{M(y)} = \frac{R\pi}{2\sqrt{6}} = \frac{\pi K_0 U_{\text{BXH}} a}{2\sqrt{6}} \quad (I-30)$$

From this expression it is evident that the value of the amplitude of interference at the output/yield of logarithmic receiver depends on the maximum factor of amplification of receiver K_0 , on the stress level of the U_{BXH} , with which begins the LAX of receiver, and coefficient a . Let us design the amplitude of interference at the output/yield of the logarithmic receiver, which has parameters $K_0 = 10^6$, $U_{\text{BXH}} = 2 \cdot 10^{-6}$; $a = 1$. The RMS value of interference according to the formula (I-30) is equal of $\sigma_{\text{nom}} = 1,27$ in. With $a = 0,434$ — $\sigma_{\text{nom}} = 0,55$ in.

Figure 4a shows the picture of stress directly on the output/yield of logarithmic receiver. The average value of output signal decreases in proportion to the increase in the range, but the value of fluctuations about the average value remains constant.

If we to the output/yield of Elogarifmicheskogo receiver after detector include/connect the high-pass filter (differentiating circuit), which does not pass the constant component of signal, at the output/yield of filter will appear the voltage, analogous to the voltage of the inherent noise of receiver (Fig. 4b).

Consequently, logarithmic receiver with the differentiating circuit at output/yield can lower the RMS value of interferences from

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mekhtnykh heterogeneities to the RMS value of internally-produced
noise of receiver.

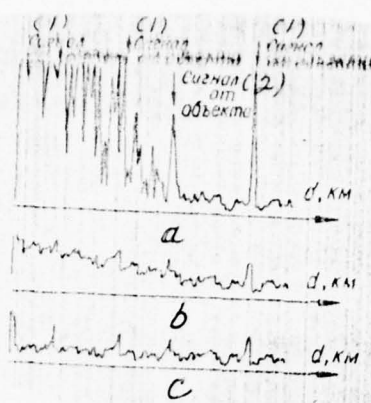


Fig. 5. The approximate form envelope of voltage on the scope of the type "A ": a) is a linear receiver; b) logarithmic receiver; c) logarithmic receiver with the differentiating circuit.

Key: (1). Signal illegible. (2). Signal from object.

For this, it is necessary that its logarithmic amplitude characteristic would begin at the level approximately on 20 dB below, but it concluded at the level 80 dB higher than RMS value of the inherent noise of receiver (which corresponds approximately to the lower and upper bound of the fluctuations of the interferences, reflected from heterogeneities).

The advantages of the logarithmic receiver before the linear are visually visible from Fig. 5, on which is depicted envelope voltages on an indicator of the type "A" (indicator with the beam deflection) for different receivers with the reception of four signals (reflected from object) and in the presence of interferences from heterogeneities. Interferences from heterogeneities, which are located on close distance from radar, impregnate linear receiver, and signal from close object it is lost (Fig. 5a). With an increase in the distance of heterogeneities, the average amplitude of interference decreases, and in this case are visible signals from object.

The logarithmic receiver with of any interference is not impregnated, but fluctuations have constant amplitude independent of the average value of the amplitude of interference (Fig. 5b). In this case are visible everything four signal from object. During the department/separation of the average value of the amplitude of interference with the aid of the differentiating circuit, the observability of the signals, reflected from object, in logarithmic receiver sharply is improved (Fig. 5c).

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In the superheterodyne receivers of radar stations LAX most expedient to obtain in UPCh, for which it is possible to utilize any of the methods, examined in chapter II.

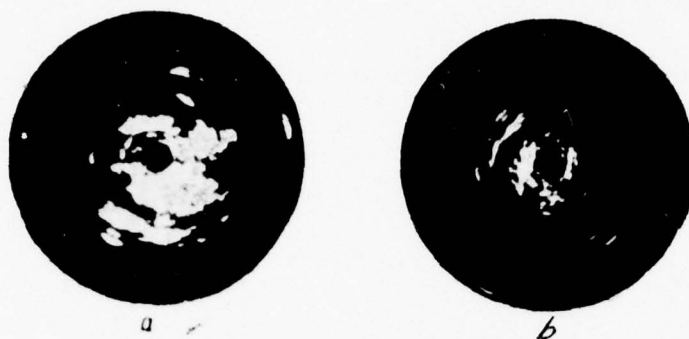


Fig. 6. Scope of the type "b" of the radar station: a) linear receiver; b) logarithmic receiver with the differentiating circuit.

In receiver in logarithmic amplitude characteristic, the delay time in the signal depends on the value of received signal and object distance. It cannot be completely taken into account during calibration and adjustment of station, and because of this appear additionally faults of measurement of the ranges, caused by the instability of the delay time of the signal in priyenike, what is an essential deficiency/lack in the logarithmic receiver. Therefore in receivers the radars of the precision determination of coordinates, it is necessary to apply logarithmic UPCh with the stable delay time in the signal.

The following deficiency/lack in the logarithmic receiver is deterioration in the relation the signal/noise at output/yield, if LAX begins from the level lower than inherent noise of receiver. Furthermore, supplementary decrease signal-to-noise ratio occurs upon the connection/inclusion of the differentiating circuit. Relation signal/noise at the output/yield of logarithmic receiver can be improved and even restore/reduced to the value of this relation at the output/yield of linear receiver, by applying video amplifier with exponential amplitude characteristic.

Figure 6 shows the scopes of the type "E" of radar station of metric range, which has linear and logarithmic receiver with the differentiating circuit.

The maximum distance along the axis of abscissas is equal to 80 km. From figure are clearly visible the advantages of the application/use of a logarithmic receiver.

On the basis of those having in the literature [33, 35] of the data on the use of logarithmic receivers it is possible to make the following conclusions.

1. Receiver with the logarithmic amplitude characteristic, which begins on 20 dB lower than RMS value of internally-produced noise, and with the differentiating circuit at output/yield can lower interference level, reflected from heterogeneities (rain, sea surface, forest etc.), almost to the level of internally-produced noise.

2. The weakening of rain clutter proceeds better than from sea surface, as a result of the correlation of the signals, reflected from the marine to powerkhnoti, from one scanning/sweep to the next.

3. The weakening of interferences from heterogeneities is obtained more effectively of radars with the worse resolution.

4. According to the special exponential characteristic of video amplifier it is possible to restore/reduce relation signal/noise to the value, which corresponds to linear receiver.

5. The deviation of experimental amplitude receiver response

from calculated logarithmic is admissible to 15-20o/o.

§3. the application/use of logarithmic amplifiers in the orienting systems and the systems of automatic homing/self-induction ¹.

FOOTNOTE ¹. Paragraph is written based on materials of foreign literature. ENDFOOTNOTE.

Applying logarithmic amplifiers it is possible to perform the orienting systems and the systems of automatic homing/self-induction with the monopulse determination of direction for the objective.

Monopulse determination is one of direction with the reception of one momentum/impulse/pulse of the signal, emitted by object. Since the receptors of the orienting system and homing system are analogous, subsequently we will examine the only orienting systems.

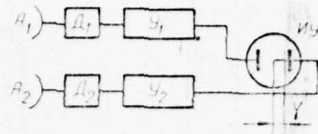


Fig. 7. The block diagram of the duplex orienting system: A_1 and A_2 are antennas of the 1st and 2nd receiving circuits; D_1 and D_2 - detectors U_1 and U_2 are logarithmic video amplifiers; IU [- integrating accelerometer] - display unit.

The system of monopulse bearing is obtained simply if we as the fundamental amplifier circuits apply logarithmic video amplifiers. The orienting system can be both duplex and single-channel.

For an increase in the sensitivity of the orienting system instead of the detector, can be applied the superheterodyne receivers with logarithmic UPCh.

Let us examine the duplex system whose block diagram is depicted on Fig. 7. Emitted by object signal is received as antennas A_1 and A_2 and at their output/yield (at the inputs of receivers) are induced the following stresses:

at the input of the first receiver

$$U'_{bx} = U_0 f'(\theta) \varphi(d);$$

at the input of the second receiver

$$U''_{bx} = U_0 f''(\theta) \varphi(d),$$

where $f'(\theta)$ and $f''(\theta)$ - the functions, which determine the dependence of the stress level of signal from direction for the objective. The character of these functions opedelyaetsya by the form of the diagram of directional radiation and the relative location in the space of antennas A_1 and A_2 ; $\varphi(d)$ - the function, which determines the dependence of the stress level of signal from object distance to.

In order to obtain the single-valued information about direction for the objective, it is necessary to remove the dependence of

information from distance to it. For this, it is necessary the stress of U'_{BX} to divide by U''_{BX} . In the case of applying logarithmic amplifiers, the division of the stresses of U'_{BX} and U''_{BX} can be replaced by subtraction by the output of these amplifiers. Let us demonstrate this.

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Output potential of amplifier Y_1 accordingly (I-17)

$$U'_{BLX} = K_0 U_{BXH} \left(a \ln \frac{U'_{BX}}{U_{BXH}} + 1 \right).$$

Output potential of amplifier Y_2

$$U''_{BLX} = K_0 U_{BXH} \left(a \ln \frac{U''_{BX}}{U_{BXH}} + 1 \right).$$

By deducting the stress of U''_{BLX} from U'_{BLX} , we will obtain

$$\begin{aligned} M = U'_{BLX} - U''_{BLX} &= K_0 U_{BXH} a \ln \frac{U'_{BX}}{U''_{BX}} = \\ &= A \ln \frac{f'(0)}{f''(0)} = F(0), \end{aligned} \quad (I-31)$$

where

$$A = K_0 U_{BXH} a.$$

Expression (I-31) - this is the unique dependence of a voltage difference on the output of logarithmic amplifiers from direction for the oriented objective. The subtraction of the stresses of U'_{BLX} and U''_{BLX} can be realized with the aid of the cathode-ray tube by means of the supply of these stresses on the opposite deflector plates. The deflection of the ray/beam of cathode-ray tube from

center of the screen γ (Fig. 7) and is the information about direction for the oriented objective.

Any deflection of the real amplitude characteristics of amplifiers from accurately logarithmic leads to the error in the opedelenii of direction.

By utilizing an expression (I-17), it is possible to demonstrate that with the assigned doputimoy relative error of $\beta = \frac{\Delta m}{m}$ in the determination of the relation of $m = \frac{U'_{ux}}{U_{ux}}$ the value of the permissible absolute deflection of the objective parameter of amplifier from accurately logarithmic at any point of it is equal

$$|\pm \Delta U_{\text{BLX}}| = 0,7 A \ln(1 + \beta). \quad (\text{I-32})$$

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In this case, the maximum permissible the relative deflection of the real amplitude characteristic of the amplifier

$$\Delta = \left| \pm \frac{\Delta U_{\text{BLX}}}{U_{\text{BLX}}} \right| = \frac{0,7a \ln(1 + \beta)}{a \ln \frac{U_{\text{ux}}}{U_{\text{uxH}}} + 1}. \quad (\text{I-33})$$

For beginning and end/lead of the logarithmic range of amplifier, the expressions Δ are different and respectively equal to:

$$\Delta_n = 0,7 a \ln(1 + \beta); \quad (\text{I-34})$$

$$\Delta_k = \frac{0,7a \ln(1 + \beta)}{\ln D + 1}, \quad (\text{I-35})$$

where D is a logarithmic range of amplifier.

At values $\delta \leq 0,05$ (or $\delta \leq 50\%$) these expressions can be recorded with a sufficient stapen'yu of the accuracy:

$$\Delta = \frac{0,7a\delta}{a \ln \frac{U_{BX}}{U_{BXH}} + 1}; \quad (I-33a)$$

$$\Delta_H = 0,7a\delta; \quad (I-34a)$$

$$\Delta_K = \frac{0,7\delta}{a \ln D + 1}. \quad (I-35a)$$

On the basis of expressions (I-33), (I-34) and (I-35) it is possible to make the following conclusions.

1. The value of the permissible absolute deflection of experimental amplitude characteristic from calculated logarithmic of the assigned error, caused by the logarithmic amplifier, the greater, the greater the maximum amplification factor and the input voltage with which begins the LAX; this value does not depend on relationship/ratio value of the compared input voltage and constantly in all logarithmic range of amplifier.

2. The permissible relative deflection of the amplitude characteristic of amplifier from calculated logarithmic - value variable decreases with an increase in the level of the compared stresses. For example if amplifier has logarithmic amplitude characteristic in the range 80 dB, then the value of the maximum permissible of the relative deflection of the experimental characteristic of amplifier at $a = 1$ and $\delta = 50\%$ in the beginning of logarithmic range is equal $\Delta_i = 3,5\%$, but at the end of the range of

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Consequently, at the end of the logarithmic K-band the amplitude characteristic of amplifier it is necessary to present more stringent requirements in the relation to the accuracy of obtaining the logarithmic law of amplification, than in the beginning range.

Everything stated above is correct for the case of the single-channel orienting system.

Thus, the logarithmic amplifiers, used in the orienting systems and the systems of automatic homing/self-induction, must at the end of the logarithmic s-band high accuracy reproduce the logarithmic law of the amplification of signals. This accuracy increases with an increase in the dynamic range of the LAX of amplifier.

§4. Application/use of logarithmic amplifiers in metrology.

In the practice of measurements, very frequently it is necessary to measure the different values, which are changed in wide dynamic range. In a number of cases of measurement, they must be counted off in logarithmic relative units - decibells or nepers.

It is known that the human perception under the effect of sonic,

light and painful factors with a sufficient degree of accuracy obeys the law of logarithm. Therefore the instruments, used during the investigation of the behavior of living organism under the effect of these factors, must have scales, calibrated completely in decibells. It should be noted that the cybernetic equipment/devices, which simulate living organism, unavoidably must contain in their composition logarithmic amplifiers.

It is possible to give another a series of the examples, which illustrate the manifestation of logarithmic law. Thus, for instance, logarithmic dependence exists between the intensity of the glow of cathode-ray tube and the value of the affecting electronic flux; between the reaction (darkening) of photographic paper and the luminous flux, which affects the paper, etc.

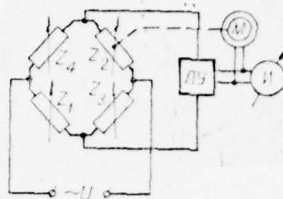


Fig. 8. The simplified circuit of balance bridge with the automatic control of zero: Z_1 , Z_2 , Z_3 , Z_4 are bridge arms; LU - logarithmic amplifier; and - null indicator; m - the motor of the automatic control of zero.

By applying logarithmic amplifiers in measuring meters, it is possible to considerably expand their measurement ranges without switching the scales and to obtain evenly divided scales directly in decibels. The instruments with the broad band of measurements without switching the scale in many instances are irreplaceable. To such instruments can be attributed:

a) the meters of the diagram of the directional radiation of antenna. The dynamic range of measurement must be not less than 100-120 dB;

b) instruments for the measurement of lumincous radiation. Dynamic range must be not less than 160-180 en. Rate meters of X-radiation and emission/radiations of atomic radiation. The dynamic range of measurements must be order 160 dB;

c) the high-speed monitors of the pressure of sound vibrations. Dynamic range of measurements to 60 dB, operating speed - less than 0.02 s.

In the instruments enumerated above it is most expedient to apply logarithmic direct-current amplifiers and speech amplifiers;

d) atomic pulse counters; counters α -, β - γ -radiations. Dynamic range of measurements to 160 dB. It is expedient to apply logarithmic video amplifiers;

e) balance alternating-currents bridge with the increased sensitivity.

Uproshchennaya diagram of this bridge with the automatic control of zero of izobrazhena in Fig. 8.

By applying logarithmic amplifier, possible: to obtain the high accuracy of automatic control in the field of zero; to ensure the work of diagram and the possibility of the visual determination of the sign of the detuning of system during the large imbalances of bridge.

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The logarithmic amplifiers, used in balance bridges, must have high entry impedance (hundred kilohm) and sufficiently large factor of amplification (10^5 - 10^6).

In conclusion one should say about the advisability of applying passive logarithmic circuits in overload ammeters, and also in the voltmeters, intended for the synchronization of two alternating-current systems upon connection/inclusion to multiple operation. Such voltmeters must according to the lower limit of the scale measure with the high accuracy of one of volt, and according to the upper limit of the scale - rough to measure the stress, which exceeds 2-3 times the nominal value of system.

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Chapter Two

METHODS OF OBTAINING LOGARITHMIC AMPLITUDE CHARACTERISTIC^S IN
AMPLIFIERS.

There are sufficiently many circuit solutions of obtaining LAX both in selective and in aperiodic amplifiers. However, as the basis of all circuit solutions, is placed the method of a change in the amplification factor and the method of the consecutive addition of stresses from the output/yields of amplifier stages.

§1. Method of a change in the amplification factor.

To change the factor of amplification of cascade/stage during an increase in the signal is possible either automatic regulirovako amplification (AGC), or by the inclusion into the diagram of nonlinear cell/elements. Logarithmic amplitude characteristic in wide dynamic range 80-100 dB can be obtained in the amplifier, which consists of n of nonlinear cascade/stages. In this case, are possible the following operating modes of nonlinear cascade/stages in amplifier, which ensure the total LAX:

a) the strictly successive work of nonlinear cascade/stages in logarithmic mode/conditions;

b) the simultaneous work of two or several nonlinear cascade/stages in nonlinear, but not logarithmic mode/conditions (combined method of obtaining LAX).

The most precise LAX of n-cascade amplifier is obtained in the strictly successive work of nonlinear cascade/stages. In this case, all amplifier stages must be identical and have completely determined amplitude characteristics, analytical expressions of which can be found, by analyzing the successive work of nonlinear cascade/stages.

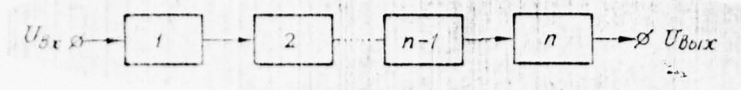


Fig. 9. Block diagram of n-cascade amplifier.

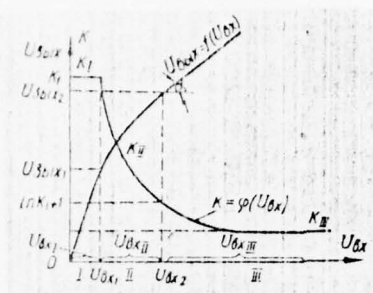


Fig. 10. Amplitude characteristic of nonlinear cascade/stage.

An analysis of the successive work of nonlinear cascade/stages.

Let us examine the successive work of nonlinear cascade/stages on the block diagram of n-cascade amplifier (Fig. 9) and let us determine the requirements by which they must satisfy nonlinear cascade/stages for obtaining precise by LAX in wide dynamic range. Since these requirements do not depend on the method of adjustment and form of the plate load of cascade/stage (single oscillatory circuit, band-pass filter, aperiodic load), the successive work of cascade/stages can be analyzed, not taking into account concrete/specific/actual circuit solution.

During analysis we assume that all cascade/stages are identical and each of them has the amplitude characteristic, depicted on Fig. 10, and the maximum amplification factor of work in linear conditions K_1 . Amplitude characteristic must consist of three sections: linear I, logarithmic II and quasi-linear III ¹.

FCOTNOTE ¹. All variables, which relate to these sections of amplitude characteristic, subsequently we will designate by corresponding indexes. ENDFCOTNOTE.

With the input voltage of the amplifier of $U_{BX} < U_{BXH}$ all cascade/stages work in linear conditions and their amplitude characteristics are described by the equation

$$U_{BUXI} = K_1 U_{BXI} \quad (II.1)$$

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When entry stress of amplifier reaches the value of $U_{BX} = U_{BXH}$, the last/latter cascade/stage enters the logarithmic mode/conditions. This corresponds on Fig. to 10 input voltage of the cascade/stage of U_{BX1} . Consequently, the input voltage of the cascade/stage with which the nachinaetya of its LAX, in the case of the n-cascade amplifier

$$U_{BX1} = U_{BXH} K_1^{n-1}.$$

During a further increase in the input voltage, the last/latter amplifier stage works in logarithmic mode/conditions, and weight preceding/previous - in linear conditions with a maximum coefficient of K_1 . It is analogous with that as it was shown in §1 chapter I, the amplitude characteristic of cascade/stage in work in logarithmic mode/conditions is described by the expression

$$U_{BXII} = K_1 U_{BX1} \left(\ln \frac{U_{BXII}}{U_{BX1}} + 1 \right) \quad \text{при } a = 1, \quad (11-2)$$

with (1)

CI

$$U_{BXII} = K_1 U_{BXI} \left(a \ln \frac{U_{BXII}}{U_{BXI}} + 1 \right) \quad \text{with } (1) \quad \text{if } a \neq 1. \quad (II-3)$$

During the introduction of relative input $x = \frac{U_{BX}}{U_{BXI}}$ and output $z = \frac{U_{BXII}}{U_{BXI}} = \frac{U_{BXII}}{K_1 U_{BXI}}$ of voltages, the expressions (II-1) and (II-3) accept the following form:

$$z_I = x_I; \quad (II-4)$$

$$z_{II} = a \ln x_{II} + 1. \quad (II-5)$$

The amplitude characteristic of cascade/stage $z = f(x)$, the expressed in relative voltages by analogy with amplifier, let us agree to call the given amplitude characteristic.

The factor of amplification of cascade/stage of work in logarithmic mode/conditions is a value variable

$$K_{II} = \frac{U_{BXII}}{U_{BXI}} = \frac{K_1 U_{BXI}}{U_{BXI}} \left(a \ln \frac{U_{BXII}}{U_{BXI}} + 1 \right). \quad (II-6)$$

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Let us assume that the LAX of cascade/stage terminates with the input voltage of U_{BXI} . Then dynamic range LAX on the input voltage

$$D_I = \frac{U_{BXI}}{U_{BXI}}. \quad (II-7)$$

Subsequently for the sake of simplicity in the analysis of the successive work of cascade/stages, let us accept coefficient of $a = 1$.

During a change in the entry stress of the n cascade/stage in the range from U_{BX1} to U_{BX2} , the entry stress of amplifier changes in the range of $\frac{U_{BX1} - U_{BX2}}{K_1^{n-1}}$.

In this case, the amplifier gain is determined by the expression

$$K_{0(n)} = K_1^{n-1} \frac{K_1 U_{BX1}}{U_{BX(n)}} \left(\ln \frac{U_{BX(n)}}{U_{BX1}} + 1 \right),$$

where $U_{BX(n)} = U_{BX1} K_1^{n-1} = U_{BXn}$ - entry stress of the n cascade/stage; U_{BX1} - entry stress of amplifier.

At the output of amplifier, is reproduced the logarithmic dependence

$$U_{BX0(n)} = U_{BX} K_{0(n)} = K_1 U_{BX1} \left(\ln \frac{U_{BX(n)}}{U_{BX1}} + 1 \right),$$

or

$$U_{BX0(n)} = K_1 U_{BX1} \left(\ln \frac{U_{BXn}}{U_{BX1}} + 1 \right) = K_0 U_{BXn} \left(\ln \frac{U_{BX}}{U_{BXn}} + 1 \right). \quad (11-8)$$

When entry stress of the n cascade/stage reaches U_{BX1} , operating point on its amplitude characteristic is located on the boundary of transition with II to III section. For the realization of the successive work of cascade/stages, it is necessary that at this moment operating point on amplitude characteristic $(n-1)$ the-go of cascade/stage would be located on the boundary of transition from I to II section, i.e., entry stress of the cascade/stage must be equally of U_{BX1} .

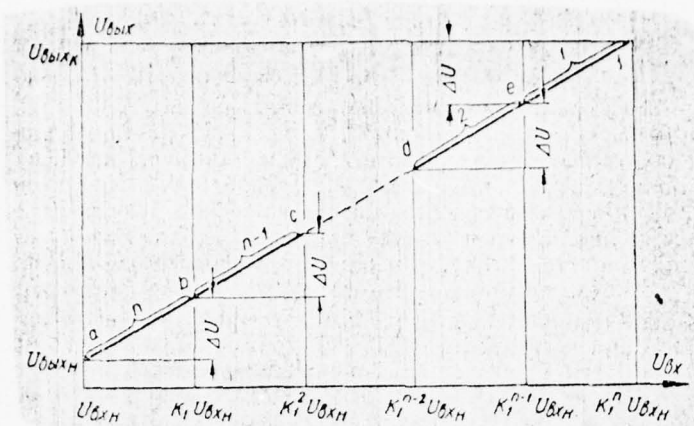


Fig. 11. Logarithmic amplitude characteristic of multistage amplifier on semilogarithmic scale.

For satisfaction of this condition, the maximum factor of amplification of nonlinear cascade/stage must be

$$K_1 = \frac{U_{BX_1}}{U_{BX_1}} = D_1. \quad (II-9)$$

Then section common/general/total by the LAX of amplifier (section a-b in Fig. 11) is obtained in work in the logarithmic mode/conditions of the n cascade/stage respectively during a change in the input voltage of amplifier from U_{BX_1} to $K_1 U_{BX_1} = D_1 U_{BX_1}$. With $U_{BX} = K_1 U_{BX_1}$ according to expression (II-8) output potential of the amplifier

$$U_{BX} = K_0 U_{BX_1} (\ln D_1 + 1) = K_0 U_{BX_1} \ln D_1 + K_0 U_{BX_1} = U_{BX_1} + \Delta U,$$

where

$$\Delta U = K_0 U_{BX_1} \ln D_1 = K_1 U_{BX_1} \ln D_1. \quad (II-10)$$

During a change in the entry stress of amplifier from

$$U_{BX} = \frac{U_{BX_1}}{K_1^{n-2}} = K_1 U_{BX_1} \quad \text{to} \quad U_{BX} = \frac{U_{BX_1}}{K_1^{n-2}} = K_1^2 U_{BX_1} \quad \text{penultimate } (n-1) - 1$$

cascade/stage works in logarithmic mode/conditions, all cascade/stages, which precede penultimate, they work in linear, and the last/latter cascade/stage in quasi-linear mode/conditions.

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In this case, the common/general/total coefficient of amplifier changes according to the law

$$K_{0(n-1)} = K_1^{n-2} \frac{K_1 U_{BX_1}}{U_{BX(n-1)}} \left(\ln \frac{U_{BX(n-1)}}{U_{BX_1}} + 1 \right) K_{11(n)}, \quad (II-11)$$

where $U_{BX(n-1)} = U_{BX} K_1^{n-2} = U_{BX_1}$ - entry stress (n-1) the-go of cascade/stage; $K_{11(n)}$ are the current factor of amplification of

the n cascade/stage.

Here all the previous cascade/stages will introduce no distortions into common amplitude characteristic, since they continue to work in the linear uchastkakh of their amplitude characteristics. The last/latter cascade/stage which in this torque/moment works in quasi-linear mode/conditions, will not introduce distortions into common logarithmic amplitude characteristic, if its factor of amplification of $K_{m(b)}$ is constant and equal to unity or will be more than unity and variable, but in this case the differential amplification factor must be equal to unity. In this case of an incremental stress on the output/yield of the n cascade/stage, will be equal to incremental stresses on its input, and section common/general/total logarithmic amplitude characteristics, caused $(n-1)$ -m by cascade/stage (section b-c in Fig. 11), will be accurately reproduced at the output/yield of the n cascade/stage, i.e., at the output of amplifier. It is necessary to note that the factor of amplification of cascade/stage of the successive work of nonlinear cascade/stages is always higher one. This escape/ensues of the following.

On the basis of equalities (II-6) and (II-9) we find the factor of amplification of nonlinear cascade/stage at the torque/moment of transition from logarithmic mode/conditions to quasi-linear

$$K_2 = \ln \frac{U_{nx_2}}{U_{nx_1}} + 1 = \ln D_1 + 1. \quad (II-12)$$

Since $D_1 > 1$ and $\ln D_1 > 0$, $K_2 > 1$.

At the transition point of the amplitude characteristic of nonlinear cascade/stage from logarithmic section to quasi-linear, is made the equality of $K_{III} = K_2$. Consequently $K_{III} > 1$.

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But if the factor of amplification of the last/latter cascade/stage of K_{III_n} is more than one and constant, then the last/latter cascade/stage will introduce distortions into common logarithmic amplitude characteristic. Distortions will develop itself in the fact that the section of common logarithmic amplitude characteristic, provided with work $(n-1)$ the-go of cascade/stage in logarithmic mode/conditions, will slope of the abrupt/steeper in comparison with slope/inclination section of characteristic, obtained in work in the logarithmic mode/conditions of the last/latter n cascade/stage.

Utilizing a condition of the equality of ordinates and first-order derivatives for the transition point of the amplitude characteristic of nonlinear cascade/stage of logarithmic section to quasi-linear, and also equality (II-9), we find the value of the differential amplification factor of the work of nonlinear cascade/stage in the quasi-linear mode/conditions

$$b = \frac{dU_{\text{max}II}}{dU_{\text{BX}II}} = \frac{dU_{\text{max}III}}{dU_{\text{BX}III}}$$

CI

$$\frac{d \left[K_1 U_{BX_1} \left(\ln \frac{U_{BX_{III}}}{U_{BX_1}} + 1 \right) \right]}{d U_{BX_{III}}} = \frac{d [K_1 U_{BX_1} (\ln D_1 + 1) + b (U_{BX_{III}} - U_{BX_1})]}{d U_{BX_{III}}}$$

After differentiation we obtain

$$\frac{K_1 U_{BX_1}}{U_{BX_1}} = b.$$

Since at transition point

$$U_{BX_1} = U_{BX_1} K_1,$$

Then

$$b = 1. \quad (11-13)$$

Thus, the differential factor of amplification of cascade/stage of work in quasi-linear mode/conditions must be equal to one. The dependence between output and input voltage on the quasi-linear section of amplitude characteristic (with $U_{BX_{III}} \geq U_{BX_1}$ in Fig. 10) can be recorded in the following form:

$$U_{BX_{III}} = U_{BX_1} + b (U_{BX_{III}} - U_{BX_1}).$$

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After simple conversions we will obtain

$$U_{BX_{III}} = K_1 U_{BX_1} \left(\ln D_1 + \frac{U_{BX_{III}}}{U_{BX_1}} \right) \quad (11-14)$$

CI

$$z_{III} = \ln D_1 + \frac{x_{III}}{D_1}. \quad (11-15)$$

Factor of amplification of nonlinear cascade/stage for this section of the characteristic

$$K_{III} = \frac{K_1 U_{BX_1}}{U_{BX_{III}}} \left(\ln D_1 + \frac{U_{BX_{III}}}{U_{BX_1}} \right),$$

or

$$K_{III} = \frac{K_1 U_{BX_1} \ln D_1}{U_{BX_{III}}} + 1. \quad (II-16)$$

From expression (II-16) it is evident that the factor of amplification of nonlinear cascade/stage of work in the quasi-linear section of amplitude characteristic is the value of variable and during a considerable increase in the input voltage it approaches unity.

After the substitution of expression (II-16) in (II-11) we obtain formula for a common/general/total amplification factor of work (n-1) the-go of nonlinear cascade/stage in the logarithmic mode/conditions

$$K_{0(n-1)} = \\ = K_1^{n-2} \frac{K_1 U_{BX_1}}{U_{BX_{(n-1)}}} \left(\ln \frac{U_{BX_{(n-1)}}}{U_{BX_1}} + 1 \right) \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX_{(n)}}} + 1 \right).$$

Respectively output potential of the amplifier

$$U_{BX_{0(n-1)}} = U_{BX} K_{0(n-1)} = K_1 U_{BX_1} \ln D_1 + \\ + U_{BX_1} K_1 \left(\ln \frac{U_{BX_{(n-1)}}}{U_{BX_1}} + 1 \right),$$

or

$$U_{BX(n-1)} = K_1 U_{BX_1} \ln D_1 + U_{BX_1} K_1 \left(\ln \frac{U_{BX11}}{U_{BX_1}} + 1 \right),$$

since

$$U_{BX(n-1)} = U_{BX11}.$$

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Consequently, at the output of entire amplifier is reproduced logarithmic amplitude characteristic. With all the increase in the input voltage into that torque/moment, kgd, the operating point on amplitude characteristic (n-2) the-go of cascade/stage will move for logarithmic section, common/general/total amplification factor and output potential of amplifier are equal to:

$$\begin{aligned} K_{0(n-2)} &= K_1^{n-3} \frac{K_1 U_{BX_1}}{U_{BX(n-2)}} \left(\ln \frac{U_{BX(n-2)}}{U_{BX_1}} + 1 \right) \times \\ &\times \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX(n-1)}} + 1 \right) \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX(n)}} + 1 \right); \\ U_{BX0(n-2)} &= U_{BX} K_{0(n-2)} = 2K_1 U_{BX_1} \ln D_1 + \\ &+ U_{BX_1} K_1 \left(\ln \frac{U_{BX(n-2)}}{U_{BX_1}} + 1 \right), \end{aligned}$$

or

$$U_{BX0(n-2)} = 2K_1 U_{BX_1} \ln D_1 + U_{BX_1} K_1 \left(\ln \frac{U_{BX11}}{U_{BX_1}} + 1 \right),$$

since

$$U_{BX(n-2)} = U_{BX11}.$$

By discussing analogously, we will obtain expressions for the

common/general/total factor of amplification and output potential of n-cascade amplifier of the work of the first nonlinear cascade/stage in the logarithmic mode:

$$K_{0(1)} = \frac{K_1 U_{BX_1}}{U_{BX}} \left(\ln \frac{U_{BX}}{U_{BX_1}} + 1 \right) \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX(2)}} + 1 \right) \dots \\ \dots \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX(n-1)}} + 1 \right) \left(\frac{K_1 U_{BX_1} \ln D_1}{U_{BX(n)}} + 1 \right); \\ U_{BX_{0(1)}} = U_{BX} K_{0(1)} = (n-1) K_1 U_{BX_1} \ln D_1 + \\ + K_1 U_{BX_1} \left(\ln \frac{U_{BX}}{U_{BX_1}} + 1 \right),$$

or

$$U_{BX_{0(1)}} = (n-1) K_1 U_{BX_1} \ln D_1 + K_1 U_{BX_1} \left(\ln \frac{U_{BX_{11}}}{U_{BX_1}} + 1 \right); (II-17)$$

since in this case of $U_{BX} = U_{BX_{11}}$,

The first nonlinear cascade/stage works in logarithmic mode/conditions during a change in the output potential of amplifier from $K_1^{n-1} U_{BX_1} = U_{BX_1}$ to $U_{BX_n} = U_{BX_1} K_1^n = U_{BX_1}$

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Section common/general/total in the LAX of amplifier, that is obtained in work in the logarithmic mode/conditions of the first cascade/stage, in Fig. 11 is designated by e-f. The designations of sections n, n-1, ..., 2, 1, given in Fig. 11, indicate the fact that this section common/general/total by the LAX of amplifier is obtained in work in the logarithmic mode/conditions respectively of cascade/stages n, (n-1), ..., 2 and the 1st.

Output potential of logarithmic amplifier at the end of the dynamic range in accordance with expression (II-17)

$$U_{\text{BIMX}_K} = nK_1 U_{\text{BX}_1} \ln D_1 + K_1 U_{\text{BX}_1} = U_{\text{BIMX}_H} + n\Delta U. \quad (\text{II-18})$$

On the basis of the given reasonings, let us record the common/general/total expression for the factor of amplification of n-cascade amplifier of the strictly successive work of the nonlinear cascade/stages

$$K_0 = K_1^{n-m} \frac{U_{\text{BX}_1} K_1}{U_{\text{BX}_1(n-m+1)}} \left[\ln \frac{U_{\text{BX}(n-m+1)}}{U_{\text{BX}_1}} + 1 \right] \prod_{i=2}^{m-1} \times \\ \times \left(\frac{K_1 U_{\text{BX}_1} \ln D_1}{U_{\text{BX}(n-m+i)}} + 1 \right), \quad (\text{II-19})$$

where (n-m) - the number of nonlinear cascade/stages, which work in linear conditions; (n-m + 1) - the number, which indicates, which nonlinear cascade/stage works in logarithmic mode/conditions; (m-1) - the number of nonlinear cascade/stages, which work in quasi-linear mode/conditions; $U_{\text{BX}(n-m+i)}$ - output potential (n-m + i) the-go of nonlinear cascade/stage.

The output potential of amplifier is determined from the formula

$$U_{\text{BIMX}_1} = K_0 U_{\text{BX}_1}. \quad (\text{II-20})$$

On the basis of the analysis conducted it is possible to draw the conclusion that during logarithmic operation according to the law of natural logarithm for obtaining a precise logarithmic amplitude characteristic of n-cascade amplifier nonlinear cascade/stages,

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independent of circuit solution, they must satisfy the following
fundamental requirements:

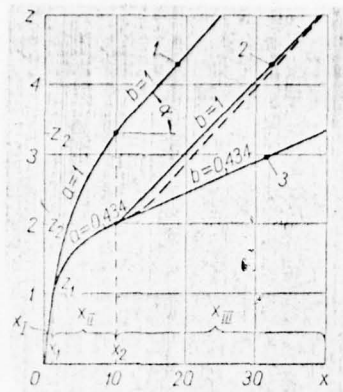


Fig. 12. Given amplitude characteristics of nonlinear cascade/stage at the different values of coefficient of a and $K_1 = D_1 = 10$.

1) the amplification of weak signals must be maximum;

2) dynamic range the LAX of nonlinear cascade/stage on input voltage must be equal to the maximum factor of amplification of this cascade/stage, i.e., $D_1 = K_1$;

3) the differential factor of amplification of nonlinear cascade/stage after having emerged of operating point on its amplitude characteristic from logarithmic section must be equal to unity. In this case, the current factor of amplification of cascade/stage must be variable and approach unity during a considerable increase in the input signal.

If logarithmic operation is conducted not by Napierian base ($a = \text{neg } 1$), the third condition $b = 1$ virtually it cannot be satisfied with high accuracy which leads to distortion common/general/total by the LAX of n-cascade amplifier. This is obtained as a result of the fact that with $(a \neq 1)$, at transition point from the logarithmic to the quasi-linear section of the amplitude characteristic of cascade/stage differential factor of amplification $b = a$. For satisfaction of condition $b = 1$ on the quasi-linear section of the amplitude characteristic of cascade/stage, it is necessary that the characteristic of cascade/stage at transition point from logarithmic section to quasi-linear would have sharp fracture (Fig. 12, is curve 2), which virtually cannot be carried out. Only during a considerable increase in the relative input voltage x coefficient b in the case of $a \neq 1$ approaches unity (Fig. 12, dashed curve). Any deviation of

the real amplitude characteristic of nonlinear cascade/stage from the required theoretical curve distorts logarithmic amplitude characteristic.

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In order to obtain a precise LAX of n-cascade amplifier with a (neg) 1, i.e., with any foundation of logarithmic operation, it is necessary in the last/latter nonlinear cascade/stage to accomplish of condition $a = b \neq 1$, and in all remaining nonlinear cascade/stages - condition $a = b = 1$.

In this case the last/latter nonlinear cascade/stage, working in quasi-linear mode/conditions, transmits to the output of amplifier an incremental stress with differential factor of amplification $b = a$ (neg) 1 and general amplitude characteristic of amplifier slopes, determined by coefficient of a (neg) 1. Besides examined curve 2, Fig. 12 also depicts the given amplitude characteristics of nonlinear cascade/stage for the cases: $a = b = 1$ (is curve 10; $a = b = 0.434$ (curve 3). In all three cases is accepted the more probable for a practice value of the factor of amplification and dynamic diapazon the LAX of cascade/stage $K_1 = D_1 = 10$.

With $a = b \neq 1$, amplitude characteristic of nonlinear cascade/stage on quasi-linear section is described by the expression

$$U_{Bx_{III}} = K_1 U_{Bx_1} \left[a \left(\ln D_1 + \frac{U_{ax_{III}}}{U_{Bx_1}} - 1 \right) + 1 \right] \quad (II-21)$$

or

$$z_{III} = a \left(\ln D_1 + \frac{x_{III}}{D_1} - 1 \right) + 1. \quad (II-22)$$

Figure as 13 solid lines on semilogarithmic scale depicts the required for a successive work given amplitude characteristics of nonlinear cascade/stage for three values of coefficient of a and $K_1 = D_1 = 10$. The logarithmic section of amplitude characteristic (from x_1 to x_2) on semilogarithmic scale is depicted as straight line.

For the general case ($a \neq 1$), when in the last/latter cascade/stage is satisfied condition $a = b \neq 1$, and in all remaining cascade/stages - $a = b = 1$, the factor of amplification of n -cascade amplifier of the strictly successive work of the cascade/stages

$$K_0 = K_1^{n-m} \frac{U_{Bx_1} K_1}{U_{Bx_{(n-m+1)}}} \left[\ln \frac{U_{Bx_{(n-m+1)}}}{U_{Bx_1}} + 1 \right] \times \\ \times \prod_{i=1}^{n-m-1} \left(\frac{K_1 U_{Bx_1} \ln D_1}{U_{Bx_{(n-m+i)}}} + 1 \right) \left[\frac{K_1 U_{Bx_1} (a \ln D_1 + 1 - a)}{U_{Bx_{(n)}}} + a \right]. \quad (II-23)$$

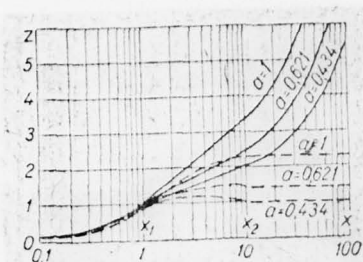


Fig. 13. Given amplitude characteristics of nonlinear cascade/stage on semilogarithmic scale.

Output potential of amplifier opedelyaetsya according to the formula (II-20), which in this case is equivalent to expression (I-17).

Is expressed fundamental qualitative indices of the n-cascade logarithmic amplifier by the indices of separate cascade/stages. Beginning the LAX of n-cascade amplifier in the successive work of nonlinear cascade/stages corresponds to the input voltage with which the last/latter cascade/stage enters the logarithmic section of its amplitude characteristic. This voltage

$$U_{BXH} = \frac{U_{BX1}}{K_1^{n-1}} \quad (II-24)$$

In this case, output potential of the amplifier

$$\begin{aligned} U_{BHXH} &= U_{BXH} K_1^n = \\ &= U_{BHX1} \end{aligned} \quad (II-25)$$

The end/lead of the logarithmic amplitude characteristic corresponds to the input voltage with which the first nonlinear cascade/stage emerges the logarithmic mode/conditions of Output voltage for this case

$$U_{BHXK} = U_{BX1} = U_{BXH} K_1^n \quad (II-26)$$

$$U_{BHXK} = nK_1 U_{BX1} a \ln D_1 + K_1 U_{BX1} = U_{BHXK} (na \ln D_1 + 1). \quad (II-27)$$

Dynamic range of logarithmic amplifier on the input voltage

$$D = \frac{U_{BHXK}}{U_{BXH}} = K_1^n = D_1^n \quad (II-28)$$

since in the successive work $K_1 = D_1$. Respectively dynamic range of amplifier on the output voltage

$$D_{\text{BLX}} = \frac{U_{\text{BLX}_K}}{U_{\text{BLX}_H}} = na \ln D_1 + 1. \quad (\text{II-29})$$

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Contraction coefficient of the amplified stress

$$C = \frac{D}{D_{\text{BLX}}} = \frac{D_1^n}{na \ln D_1 + 1}. \quad (\text{II-30})$$

From expressions (II-28) - (II-30) it is evident that the dynamic range of logarithmic amplifier on input voltage can be changed by changing the dynamic range of the LAX of cascade/stages and their number. The dynamic range of amplifier on output voltage and, consequently, also the compression ratio with the constant D_1 can be decreased or increased by changing coefficient of a .

The characteristics, shown in Fig. 2, in the successive work of the cascade/stages, which have the most probable value $K_1 = D_1 = 10$, they are the characteristics of five-stage amplifier. The analysis conducted shows that in the strictly successive work of cascade/stages for obtaining precise by the LAX of n -cascade amplifier in wide dynamic range in the case of the amplification of signal according to the law of natural logarithm ($a = 1$) all cascade/stages of dlyhny to be identical and to have the amplitude characteristics, described on individual sections by expressions (II-1), (II-2) and (II-14). In the case of amplification according to the law of logarithm with any

foundation (a (neq) 1) all cascade/stages, which precede the latter, must be identical and have the amplitude characteristics, also described by expressions (II-1), (II-2) and (II-14). The last/latter cascade/stage must have the amplitude characteristic, described by expressions (II-1), (II-3) and (II-21). In this case, the quasi-linear section of amplitude characteristic, described by expression (II-14) or (II-21), of the first cascade/stage must be absent, and in the latter - to be greatest on extent.

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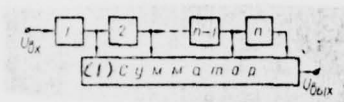
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§ 2. Method of the consecutive addition of voltages from the output/yields of amplifier stages.

Fig. 14. Simplified block diagram of n-cascade amplifier.

Key: (1). Summator.



A method of the consecutive addition of voltages from the output/yields of cascade/stages can be utilized for obtaining LAX in n-cascade selective and aperiodic amplifiers. The special case of this general method, the method of consecutive detection, which is applied for obtaining LAX in selective amplifiers, are examined in works [26], [34], [38] and [43]. It should be noted that in these works the indicated method of obtaining LAX is examined insufficiently fully. In this paragraph the author made the attempt to deepen analysis, after examining the more general case.

The principle of obtaining LAX with the method of the addition of voltages let us examine on the simplified block diagram of n-cascade amplifier, depicted on Fig. 14.

Amplifier consists of n of amplifier stages (1, 2, ..., n - 1, n) whose output/yields are connected to the summator of voltages. From the output/yield of summator, is remove/taken the output voltage, equal to the sum of the voltages of all amplifier stages.

By examining the work of diagram, let us suppose that:

all cascade/stages are identical and have a factor of amplification K_1 ;

the amplitude characteristic of each cascade/stage up to saturation remains linear;

during the saturation of cascade/stage its output voltage does not depend on the amplitude of input signal and remains constant;

summator linearly summarizes voltages with transmission factor, equal to unity.

After input process of the amplifier of small voltages, the cascade/stages work without overloadings in linear conditions. Let us assume that with entry stress of the amplifier of $U'_{BX} = U_{BX_0}$ the last/latter n cascade/stage is impregnated and from its output/yield is remove/taken the stress of $U_{BX_1} = K_1^n U_{BX_0}$. Since to summator are connected the output/yields of all cascade/stages, output potential of the summator

$$U'_{BX} = U_{BX_0} = K_1^n U_{BX_0} + U_{BX_0} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^2 + K_1) = K_1^n U_{BX_0} + \Delta U'.$$

During an increase in the output potential of amplifier from $U'_{BX} = U_{BX_0}$ to $U''_{BX} = K_1 U_{BX_0}$ output potential of summator changes according to the law

$$U_{BX_0(n)} = K_1^n U_{BX_0} + U_{BX_0} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^2 + K_1). \quad (11-31)$$

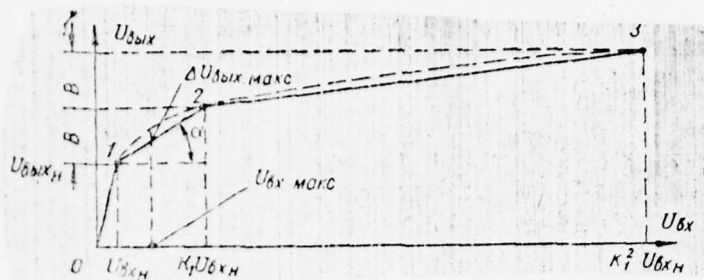
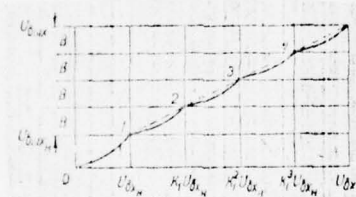


Fig. 15. Initial section calculated and experimental by the LAX of the amplifier of $B = K_1^n U_{rxH}$.

Fig. 16. Amplitude characteristics of amplifier in obtaining LAX with the method of the addition of the stresses: ----- the calculated LAX; — the experimental LAX of $B = K_1^n U_{rxH}$.



The section of the common amplitude characteristic of amplifier, which is obtained with the overloading of the last/latter nonlinear cascade/stage and described by expression (II-31), is linear. This section in Fig. 15 and 16 is designated in numerals 1-2. Figure 15 shows the initial part of the common amplitude characteristic of amplifier on graphic scale along the axes of coordinates during the saturation of the last/latter and penultimate cascade/stages (cuts, depicted as solid line). Figure 16 experimental amplitude characteristic of amplifier shows unbroken curve on semilogarithmic scale (along the axis of abscissas is taken logarithmic scale, and along the axis of ordinates - linear).

With the input voltage of the amplifier of $U_{BX}'' = K_1 U_{BX_H}$ is impregnated penultimate $(n - 1) - 1$ cascade/stage and output potential of the summator

$$\begin{aligned} U_{LIX}'' &= 2K_1^n U_{BX_H} + U_{BX_H} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^2) = \\ &= 2K_1^n U_{BX_H} + \Delta U''. \end{aligned}$$

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If the number of cascade/stages $n \gg 1$, then with a sufficient degree of accuracy is fulfilled the equality

$$\Delta U' = \Delta U''.$$

Then the voltage

$$U_{LIX}'' = U_{LIX_H} + K_1^n U_{BX_H}.$$

This it corresponds to point 2 in Fig. 15 and 16.

During a change in the input voltage of amplifier from U''_{bx} to $U'''_{bx} = K_1^2 U_{bxH}$, when is saturated $(n - 1) - 1$ cascade/stages, output potential of the summator

$$U_{bLX0(n-1)} = 2K_1^n U_{bxH} + U_{bx} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^2).$$

This section of amplitude characteristic in Fig. 15 and 16 are designated in 2-3 and is linear.

With the input voltage of amplifier, the U'''_{bx} is impregnated $(n - 1) - 1$ cascade/stages and output potential of the summator

$$\begin{aligned} U'''_{bLX} &= 3K_1^n U_{bxH} + U_{bxH} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^3) = \\ &= 3K_1^n U_{bxH} + \Delta U''' = U_{bLXH} + 2K_1^n U_{bxH}, \end{aligned}$$

since with $n \gg 1$

$$\Delta U''' = U_{bxH} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^3) \cong \Delta U''.$$

Analogously it is possible to record, that with

$$U_{bx}^{(i)} = K_1^{i-1} U_{bxH} \quad (II-32)$$

$$\begin{aligned} U_{bLX}^{(i)} &= iK_1^n U_{bxH} + U_{bxH} (K_1^{n-1} + K_1^{n-2} + \dots + K_1^i) = \\ &= U_{bLXH} + (i - 1) K_1^n U_{bxH}, \end{aligned} \quad (II-33)$$

while with

$$U_{bx}^{(n)} = K_1^{n-1} U_{bxH} = U_{bxK}, \quad (II-34)$$

when is impregnated the first cascade/stage, output potential of the summator

$$U_{bLX}^{(n)} = U_{bLXK} = nK_1^n U_{bxH}. \quad (II-35)$$

Thus, during a change in the input voltage in exponential function, output voltage changes linearly. This gives the logarithmic dependence between output and input voltage.

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It is possible to show that in the case in question for the input voltage with which consecutively are overloaded the cascade/stages, there is a precise logarithmic dependence. For this, from expression (II-32) let us find

$$i = \frac{1}{\ln K_1} \ln \frac{U_{BX}^{(i)}}{U_{BXH}} + 1$$

and, after substituting into expression (II-33), we will obtain

$$U_{BX}^{(i)} = \frac{K_1^i U_{BXH}}{\ln K_1} \ln \frac{U_{BXH}}{U_{BXH}} + U_{BXH} \sum_{a=1}^{a=i} K_1^{n-a+1}, \quad (\text{II-36})$$

where i - the number, which shows, which cascade/stage is saturated with this input voltage.

Let us find the fundamental principles, which characterize the LAX of n -cascade amplifier. Since the LAX of amplifier begins and terminates respectively with the input voltage of U_{BXH} and $U_{BXK} = U_{BXH} K_1^{n-1}$, the dynamic range of amplifier on the input voltage

$$D = \frac{U_{BXK}}{U_{BXH}} = K_1^{n-1}. \quad (\text{II-37})$$

The dynamic range LAX, which is necessary to one cascade/stage,

$$D_1 = \sqrt[n]{D} = K_1^{\frac{n-1}{n}}. \quad (II-38)$$

From expression (II-37) we find the factor of amplification of one cascade/stage

$$K_1 = \sqrt[n]{D}. \quad (II-39)$$

Comparing the right sides of the expressions (II-36) and (I-17), we obtain

$$a = \frac{1}{\ln K_1}. \quad (II-40)$$

Taking into account that the $U_{\text{BUXH}} = U_{\text{BXH}} \sum_{i=1}^n K_1^i$, are dynamic range the LAX of amplifier on the output voltage

$$D_{\text{BUX}} = \frac{U_{\text{BUXR}}}{U_{\text{BUXH}}} = \frac{n K_1^n}{\sum_{i=1}^n K_1^i}. \quad (II-41)$$

With the sufficiently large factor of amplification of $D_{\text{BUX}} \approx n$.

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Expression (II-36) is correct only for the isolated points of the experimental amplitude characteristic of amplifier (point 1, 2 and 3 in Fig. 16). The position of intermediate points depends both on the form of the amplitude characteristics of separate/individual cascade/stages and on the value of the transmission factor of the summator, which is changed during a change in the stress level. Under the taken assumption that the cascade/stages have linear

characteristics up to saturation, the intermediate points of experimental characteristic will considerably differ from accurately logarithmic (dashed curve in Fig. 15 and dash straight line in Fig. 16). Let us find the maximum relative deflection of the δ_{max} of the experimental amplitude characteristic of amplifier from accurately logarithmic for input voltage from U_{BXH} to $U_{\text{BXH}} K_1$ (Fig. 15). On the section in question a precise LAX is described by the expression

$$U_{\text{BAXT}} = U_{\text{BAXH}} + \frac{K_1^n U_{\text{BXH}}}{\ln K_1} \ln \frac{U_{\text{BX}}}{U_{\text{BXH}}}, \quad (\text{II-42})$$

a experimental amplitude characteristic - by the expression

$$U_{\text{BAXS}} = U_{\text{BAXH}} + (U_{\text{BX}} - U_{\text{BXH}}) K_d = U_{\text{BAXH}} + (U_{\text{BX}} - U_{\text{BXH}}) \frac{K_1^n}{K_1 - 1}, \quad (\text{II-43})$$

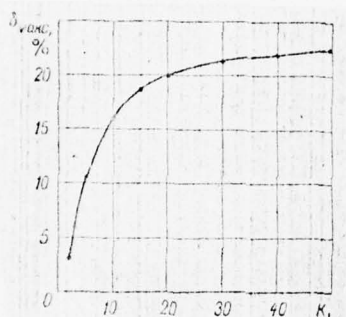
where the $K_d = \text{tg } \alpha = \frac{K_1^n}{K_1 - 1}$ - differential amplification factor on section from aaaaa to the U_{BXH}

$$U_{\text{BXH}} K_1.$$

We find a difference in the expressions (II-42) and (II-43)

$$\Delta U_{\text{BAX}} = U_{\text{BAXT}} - U_{\text{BAXS}} = \frac{K_1^n U_{\text{BXH}}}{\ln K_1} \ln \frac{U_{\text{BX}}}{U_{\text{BXH}}} - (U_{\text{BX}} - U_{\text{BXH}}) \frac{K_1^n}{K_1 - 1}. \quad (\text{II-44})$$

Fig. 17. Curve/graph of the dependence of the maximum relative error experimental by the LAX of amplifier on the value of the factor of amplification of cascade/stage.



For the search of the maximum absolute deflection of the ΔU_{BX} of experimental characteristic from the otchnoy by LAX we differentiate differences (II-44) and equate to its zero

$$\frac{d(\Delta U_{\text{BX}})}{dU_{\text{BX}}} = \frac{U_{\text{BXH}}}{U_{\text{BX}}} \cdot \frac{K_1^n}{\ln K_1} \cdot \frac{K_1^n}{K_1^n - 1} = 0,$$

whence

$$U_{\text{BX, MAX}} = \frac{U_{\text{BXH}} (K_1 - 1)}{\ln K_1}$$

and,

$$U_{\text{BX, MAX}} = U_{\text{BXH}} + \frac{K_1^n U_{\text{BXH}}}{\ln K_1} \ln \frac{K_1 - 1}{\ln K_1}.$$

Then:

$$\Delta U_{\text{BX, MAX}} = \frac{K_1^n U_{\text{BXH}}}{\ln K_1} \left(\ln \frac{K_1 - 1}{\ln K_1} - 1 + \frac{\ln K_1}{K_1 - 1} \right); \quad (\text{II-45})$$

$$\begin{aligned} \delta_{\text{MAX}} &= \frac{\Delta U_{\text{BX, MAX}}}{U_{\text{BX}}} = \\ &= \frac{\ln \frac{K_1 - 1}{\ln K_1} + \frac{\ln K_1}{K_1 - 1} - 1}{\ln \frac{K_1 - 1}{\ln K_1} + \ln K_1 \left(1 + \frac{1}{K_1} + \frac{1}{K_1^2} + \dots + \frac{1}{K_1^{n-1}} \right)}. \end{aligned} \quad (\text{II-46})$$

With the search of δ_{MAX} by means of equating to zero of derived $\frac{d(\Delta U_{\text{BX}})}{dU_{\text{BX}}} = 0$ is obtained the transcendental equation, graphoanalytical solution of which showed that the results coincide with the results, found from expression (II-46).

Curved $\delta_{\text{MAX}} = f(K_1)$ (Fig. 17) it shows that in the case of the strictly linear amplitude characteristics of cascade/stages the experimental amplitude characteristic of amplifier has sufficiently large deflections from precise as LAX. These deflections grow/rising with an increase of the factors of amplification of cascade/stages K_1 .

A precise LAX of n-cascade amplifier at any value K_1 can be obtained only with the completely determined amplitude characteristics of cascade/stages. The required characteristic of cascade/stage it is easy to find, on the strength of the successive work of nonlinear cascade/stages, examined in the preceding/previous paragraph. Let us assume that the LAX of n-cascade amplifier must begin with the input voltage of U_{BXH} . Then for obtaining precise as the LAX of amplifier cascade/stages must have the following amplitude characteristics. During a change in the entry stress of the i cascade/stage from 0 to $U_{BX_i} = U_{BXH} K_1^{i-1}$ all cascade/stages, with the exception of the first, must have linear characteristic with factor of amplification $K'_1 = K_1 - 1$, since

$$U_{BX_i} = U_{BX_1} K_1 - U_{BX_1} = (K_1 - 1) U_{BX_1} = K'_1 U_{BX_1} \quad (II-47)$$

or

$$z = \frac{K_1 - 1}{K_1}, \quad (II-48)$$

where K_1 is the factor of amplification of cascade/stage, calculated not allowing for reaction to the output voltage of the preceding/previous cascade/stages.

For the i cascade/stage

$$U_{BX_i} = U_{BX} \sum_1^i K_1^{i-1},$$

where the U_{BX} - entry stress of amplifier.

The first cascade/stage must have the linear characteristic with factor of amplification K_1 , described by expressions (II-1) and (II-4).

During a change in the entry stress of the i cascade/stage from U_{BX_1} to $U_{BX_2} = K_1 U_{BX_1}$ stress on its output/yield must change according to the law

$$U_{BX_{II}} = K_1 U_{BX_1} \left(a \ln \frac{U_{BX_{II}}}{U_{BX_1}} + 1 \right) - U_{BX_{II}} \quad (II-49)$$

or

$$z_{II} = a \ln x_{II} + 1 - \frac{x_{II}}{D_1} \quad (II-50)$$

The first cascade/stage must have the amplitude characteristic, described by expressions (II-3) and (II-5). In this case, dynamic range. LAX on the input voltage of one cascade/stage $D_1 = K_1$.

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With the input voltage of the cascade/stage of $U_{BX_{III}} > U_{BX_2}$ the output potential of each cascade/stage must remain constant and be equal to

$$U_{BX_{III}} = K_1 U_{BX_1} a \ln D_1 \quad (II-51)$$

or

$$z_{III} = a \ln D_1 \quad (II-52)$$

Given amplitude characteristics of cascade/stage $z = f(x)$, calculated from formulas (II-48), (II-50) and (II-52) for the different values of coefficient of a and $K_1 = 10$, izobrajeny wtrixami Na Ris. 13. these curves can be used during the calculation of amplifier from LAX.

During the fulfillment of equalities (II-48), (II-50) and (II-52) the general amplitude characteristic of amplifier accurately logarithmic, is described by expression (I-17) or (I-21) and amplifier has parameters, determined by equalities (II-28), (II-29) and (II-30).

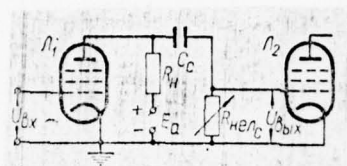
From the analysis conducted it is evident that both examined methods make it possible to obtain a precise LAX of amplifier only during a change in the factors of amplification of cascade/stages in the completely determined law during an increase in the input voltage. Are examined below the methods of a change in the factor of amplifications, which make it possible to obtain the required amplitude characteristic of nonlinear cascade/stage.

§ 3. Shunting of the plate load of cascade/stage by nonlinear cell/element.

The simplified circuit of cascade/stage with the plate load, shunted by nonlinear cell/element, is depicted on Fig. 18. Under the load impedance of R_n one should understand for an aperiodic amplifier the anode resistance of aaaa for a selective amplifier - the

equivalent resistance of the duct of the R_{01} of the shunted by resistance R_{02} . With an increase in the voltage of the signal, applied to nonlinear cell/element, the active entry impedance of $R_{ax} = R_{rec}$ decreases, which causes a decrease in the factor of amplification of cascade/stage. It is possible to select this nonlinear cell/element at whose resistance of R_{rec} changes according to the determined law, which ensures obtaining the necessary amplitude characteristic of cascade/stage.

Fig. 18. The simplified circuit of cascade/stage with the plate load, shunted by nonlinear cell/element.



As nonlinear cell/elements can be used vacuum or semiconductor diodes. In the case of selective amplifiers, the diodes must be included in such a way that conductivity for the positive and negative half-waves of the voltage of signal would be identical. It is most expedient to apply germanium semiconductor diodes of the type of DGQ1DGQ10, D2A-D2J and D9A-D9J and silicon diodes of the type of D101-D102.

On the basis of the requirement for the provision for a strictly successive work of nonlinear cascade/stages, let us find the law of a change in the resistance of nonlinear cell/element. For this, we utilize the equivalent diagram of cascade/stage, depicted on Fig. 19. On this diagram R_0 - the common/general/total load impedance of cascade/stage not allowing for the resistance of nonlinear cell/element, determined by the expression

$$\frac{1}{R_0} = \frac{1}{R_{\text{blax}}} + \frac{1}{R_a} + \frac{1}{R_{oe}} + \frac{1}{R_{\text{bx}}},$$

where the R_{blax} is output lamp resistance;

R_{bx} - the entry impedance of the following tube.

For an aperiodic amplifier the resistance of R_{oe} is absent. Factor of amplification of the cascade/stage

$$K = S \frac{R_0 R_{\text{neпc}}}{R_0 + R_{\text{neпc}}}. \quad (\text{II-53})$$

In this case, output potential of the nonlinear cascade/stage

$$U_{\text{blax}} = S U_{\text{bx}} \frac{R_0 R_{\text{neпc}}}{R_0 + R_{\text{neпc}}}. \quad (\text{II-54})$$

Fig. 19 shows that the voltage of signal on the output/yield of cascade/stage is completely applied to nonlinear cell/element, i.e.,

$U_{\text{вых}} = U_{\text{нел.}}$ In the work of cascade/stage in linear conditions when entry stress varies from 0 to $U_{\text{вх1}}$, a output potential is from 0 to $U_{\text{вых1}} = K_1 U_{\text{вх1}}$, that it corresponds to a change in the relative stresses x and z from 0 to 1, the factor of amplification of cascade/stage must be the maximum and constant.

Fig. 19. Equivalent diagram of cascade/stage with the plate load, shunted by nonlinear cell/element.



For satisfaction of this condition, the resistance of the nonlinear cell/element of R_{nonl} must be considerable and constant and must not shunt plate load, i.e., must be fulfilled the inequality

$$R_{\text{nonl}} \gg R_0. \quad (\text{II-55})$$

Then the maximum factor of amplification of the cascade/stage

$$K_1 = SR_0. \quad (\text{II-56})$$

We find the necessary law of a change of the resistance of the nonlinear cell/element of R_{nonl} depending on that which was applied to it the vykhodnog of the voltage of signal at the work of cascade/stage in logarithmic mode. This corresponds to a change in the input voltage from U_{bx_1} to $U_{\text{bx}_2} = D_1 U_{\text{bx}_1}$ and output voltage from U_{vix_1} from $U_{\text{vix}_2} = K_1 U_{\text{bx}_1} (a \ln D_1 + 1)$. In this case, relative voltage changes from $x_1 = 1$ to $x_2 = D_1$, and voltage z is from $z_1 = 1$ to $z_2 = a \ln D_1 + 1$. Utilizing equations (II-3) and (II-54), is expressed the input voltage by the output:

$$U_{\text{vix}_{II}} = U_{\text{bx}_{II}} e^{\frac{z-1}{a}}; \quad (\text{II-57})$$

$$U_{\text{bx}_{II}} = \frac{U_{\text{vix}_{II}} (R_0 + R_{\text{nonl}_{II}})}{SR_0 R_{\text{nonl}_{II}}}. \quad (\text{II-58})$$

Equating the right sides of these expressions

$$U_{\text{bx}_1} e^{\frac{z-1}{a}} = \frac{U_{\text{vix}_{II}} (R_0 + R_{\text{nonl}_{II}})}{SR_0 R_{\text{nonl}_{II}}},$$

we find the law of a change in the resistance of the nonlinear cell/element

$$R_{\text{нел II}} = \frac{R_0}{\frac{z-1}{e^{\frac{a}{R}} - 1}} \quad (\text{II-59})$$

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The resistance of $R_{\text{нел II}}$ in the successive work of nonlinear cascade/stages is calculated from formula (II-59) for the relative output voltage z , which varies from $z_1 = 1$ to $z_2 = a \ln D_1 + 1$. Substituting the value of z in expression (II-59), we obtain the law of a change of the resistance of nonlinear cell/element depending on the input voltage

$$R_{\text{нел II}} = \frac{R_0 (a \ln x + 1)}{x - a \ln x - 1} \quad (\text{II-60})$$

Utilizing expressions (II-21) and (II-54), analogously we find the law of a change of the resistance of nonlinear cell/element in the work of cascade/stage in the quasi-linear mode/conditions

$$R_{\text{нел III}} = \frac{R_0}{\frac{D_1}{a^2} (z - a \ln D_1 - 1 + a) - 1} \quad (\text{II-61})$$

For the calculation of the resistance of $R_{\text{нел III}}$ according to the formula (II-61) necessary of the value of relative output voltage to substitute from z_2 that it corresponds to the beginning of the quasi-linear section of the amplitude characteristic of cascade/stage,

to $z_3 = \sum_{i=1}^{i=z_L} i a \ln D_1 + 1$, which corresponds to the end/lead of the quasi-linear section of the amplitude characteristic of the i nonlinear cascade/stage of n-cascade amplifier.

With $z \gg \ln D_1$

since $R_{\text{nealIII}} \rightarrow \frac{1}{S}$,
 $D_1 = K_1 = SR_0$.

After substituting expression (II-22) into equation (II-61), we will obtain the law of a change of the resistance of the nonlinear cell/element of R_{nealIII} depending on the input voltage

$$R_{\text{nealIII}} = \frac{R_0 \left[a \left(\ln D_1 + \frac{x}{D_1} - 1 \right) + 1 \right]}{x - a \left(\ln D_1 - 1 + \frac{x}{D_1} \right) - 1}. \quad (\text{II-62})$$

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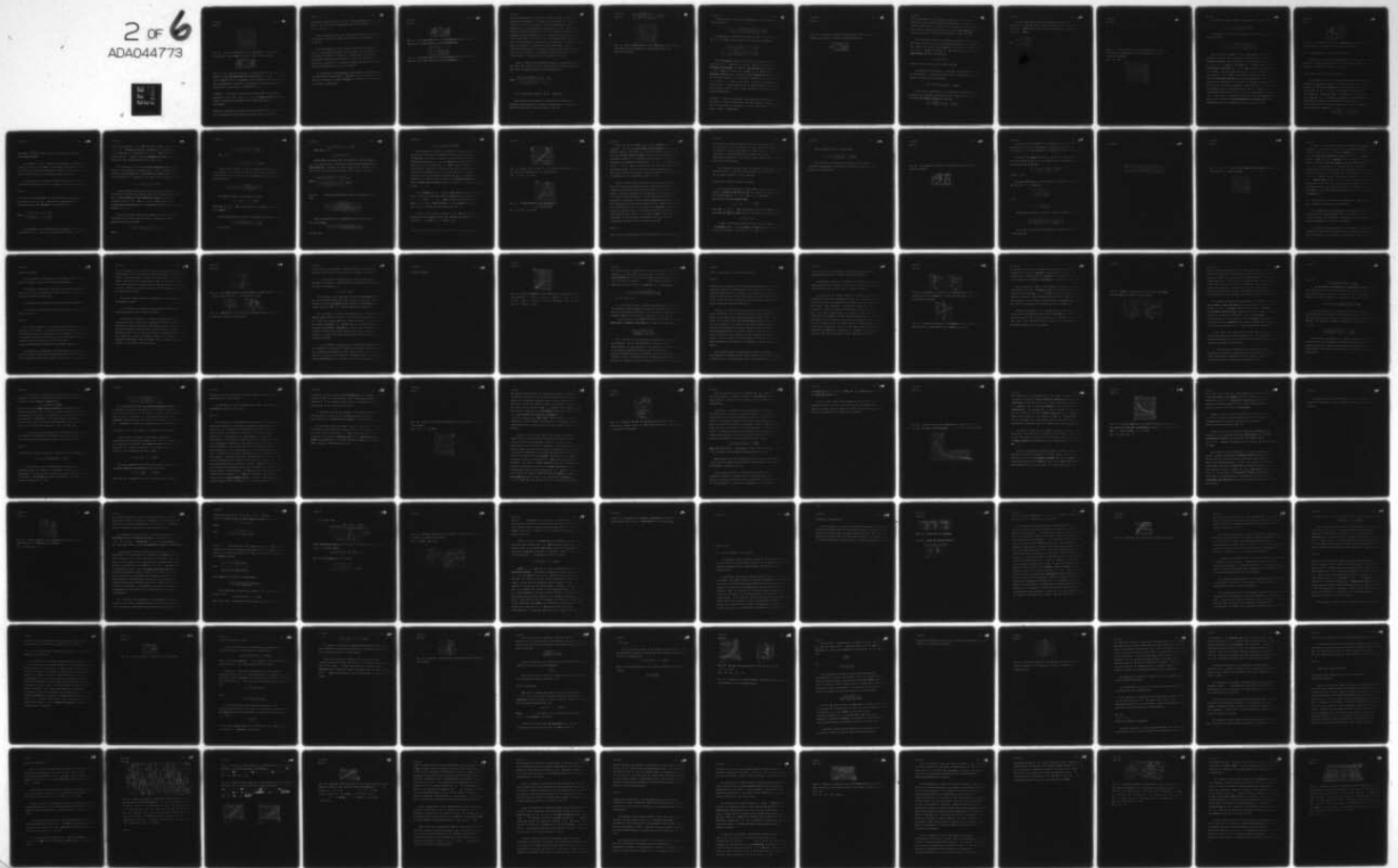
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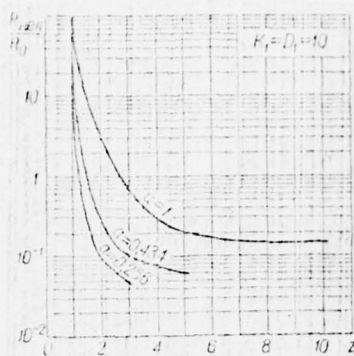


Fig. 20. Given curved changes in the resistance of the nonlinear cell/element, which shunts the plate load of cascade/stage.

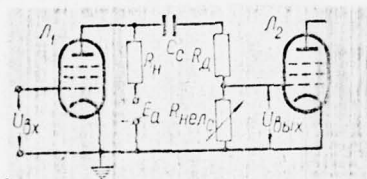


Fig. 21. The simplified circuit of cascade/stage with the plate load, shunted by 1st type nonlinear divider/denominator. z is N_p Fig. 20 depicts curved $\frac{R_{n\text{er}}}{R_0} = f(z)$, calculated from formulas (II-59) and (II-61) for the last/latter nonlinear cascade/stage of four-stage logarithmic amplifier at three values of coefficient of a .

FOOTNOTE 1. The number of nonlinear cascade/stages of logarithmic amplifier n can be any. With $n = 4$, it is already possible sufficiently to explain the character of the curves of $\frac{R_{n\text{er}}}{R_0} = f(z)$.
ENDFOOTNOTE.

During the calculation is taken the most probable case $K_1 = D_1 = 10$.
For all remaining nonlinear cascade/stages, which precede the

last/latter cascade/stage, the curved $\frac{K_{\text{нел}}}{K_0} = f(z)$ are part of the given curves. For the fourth cascade/stage of $z_{\text{max}} = na \ln D_1 + 1 = 4 a \ln 10 + 1 = 9.2 a + 1$.

Curves, depicted on Fig. 20, can be used during the calculation of amplifiers from LAX at three values of base of logarithm $N = 2.7$; 10 and 50.

With the shunting of plate load by nonlinear cell/element the range of logarithmic amplitude characteristic in one cascade/stage it is possible to obtain to 18-20 dB. Consequently, for obtaining logarithmic amplitude characteristic in the range 80-100 dB it is necessary to undertake 4-5 nonlinear cascade/stages with the maximum factor of amplification $K_1 = D_1 = 18-20$ dB.

If consecutively with nonlinear cell/element to include/connect the effective resistance of R_n , as shown in Fig. 21 and 22, then is added one additional degree of freedom in a change in the resistance of nonlinear cell/element.

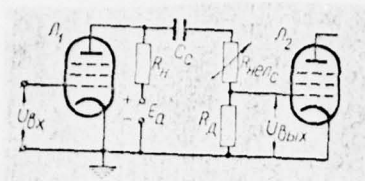


Fig. 22. The simplified circuit of cascade/stage with the plate load, shunted by 2nd type nonlinear divider/denominator.

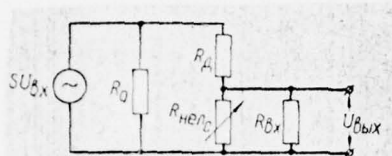


Fig. 23. Equivalent diagram of cascade/stage with the plate load, shunted by 1st type nonlinear divider/denominator.

The chain/network, which consists of active linear resistance and nonlinear cell/element, is connected by diagram in Fig. 21, let us agree to call 1st type nonlinear divider/denominator, upon the switching on of cell/elements by diagram in Fig. 22 - by 2nd type nonlinear divider/denominator. With the shunting of plate load by nonlinear divider/denominator it is possible to obtain range LAX in one cascade/stage to 28-30 dB, i.e., considerably more than in the case of the shunting of load only by one nonlinear cell/element. This makes it possible to effectively utilize tubes with a large slope/transconductance of the type of 6J9P, 6J11P, 6J20P and others, with the aid of which it is possible to obtain the large factor of amplification of cascade/stage at frequencies 30-60 MHz.

Figure 23 depicts the equivalent diagram of cascade/stage with the plate load, shunted by first type nonlinear divider/denominator. The factor of amplification of this cascade/stage

where

$$K = S \frac{R_0 R_{\text{нел}} R_{\text{вх}}}{(R_{\text{нел}} + R_{\text{вх}})(R_0 + R_A) + R_{\text{нел}} R_{\text{вх}}}, \quad (11-63)$$

$$\frac{1}{R_0} = \frac{1}{R_{\text{вх}}} + \frac{1}{R_A} + \frac{1}{R_{\text{oe}}}.$$

For the aperiodic amplifier of R_{oe} is absent.

Analogously it is possible to find that the resistance of nonlinear cell/element in the work of cascade/stage in logarithmic mode/conditions must change according to the law

$$R_{\text{нелл}} = \frac{R_{\text{вх}} (R_0 + R_{\text{д}})}{\left(\frac{e}{z} - 1 \right) R_{\text{вх}} - R_0 - R_{\text{д}}} \quad (\text{II-64})$$

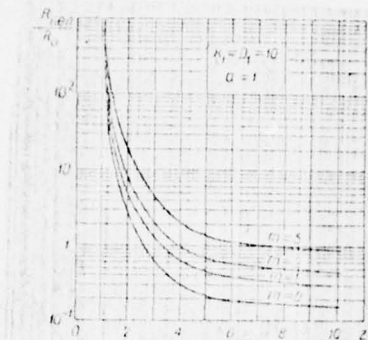


Fig. 24. Given curved changes in the resistance of the nonlinear cell/element, which enters the composition of 1st type divider/denominator.

Respectively in the work of cascade/stage in the quasi-linear mode/conditions

$$R_{\text{nonlin}} = \frac{R_{\text{bx}}(R_0 + R_A)}{\left[\frac{D_1}{a^2} (z - a \ln D_1 - 1 + a) - 1 \right] R_{\text{bx}} - R_0 - R_A}. \quad (\text{II-65})$$

In the case of applying tubes with the high the entry impedance of ($R_{\text{bx}} \gg R_0$), expressions (II-64) and (II-65) are simplified:

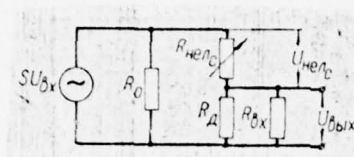
$$R_{\text{nonlin}} = \frac{R_0}{\frac{e^a}{e} - 1} \left(1 + \frac{R_A}{R_0} \right); \quad (\text{II-66})$$

$$R_{\text{nonlin}} = \frac{R_0}{\frac{D_1}{a^2} (z - a \ln D_1 - 1 + a) - 1} \left(1 + \frac{R_A}{R_0} \right). \quad (\text{II-67})$$

From expressions (II-66) and (II-67) it follows, that the resistance of R_A affects the law of a change in the resistance of nonlinear cell/element the greater, the greater the ratio/relation of $m = \frac{R_A}{R_0}$. Figure 24 depicts the curved $\frac{R_{\text{non}}}{R_0} = f(z)$ for the fourth nonlinear cascade/stage, calculated from formulas (II-66) and (II-67) for different values of m . During the calculation it is accepted $K_1 = D_1 = 10$ and $a = 1$. These curves can be used for the calculation of the four-stage logarithmic amplifier, which consists of nonlinear cascade/stages with the plate loads, shunted by first type nonlinear divider/denominators.

FCOTNOTE 1. For the calculation of the amplifier, which consists of the number of cascade/stages more than four, curves, depicted on Fig. 24, it is necessary to calculate for great significance of relative output voltage. ENDFOOTNOTE.

Fig. 25. Equivalent diagram of cascade/stage with the plate load, shunted by 2nd type nonlinear divider/denominator.



For this purpose, of the ordinate of curves it is necessary to multiply by the concrete/specific/actual value of resistance R_0 . Curves, shown in Fig. 20, also can be used during the calculation of this type of logarithmic amplifier, for which the ordinate of these curves necessary to multiply by the factor of the $R_0 \left(1 + \frac{R_n}{R_0}\right)$.

The equivalent diagram of cascade/stage with the plate load, shunted by second type nonlinear divider/denominator, is shown in Fig. 25. Taking into account that usually is fulfilled the inequality of $R_n \ll R_{BX}$ (R_n - unity the kilohm, R_{BX} are dozen kilohm), the factor of amplification of this cascade/stage

$$K = S \frac{R_0 R_n}{R_0 + R_n + R_{\text{нел}}},$$

where value R_0 the same as in formula (II-63).

Analogously the resistance of nonlinear cell/element in the work of cascade/stage in linear conditions must be the minimum, constant and be determined by the expression

$$R_{\text{нел}} = \frac{SR_0 R_n}{K_1} - R_0 - R_n = \text{const.} \quad (\text{II-68})$$

In the work of cascade/stage in logarithmic mode/conditions the resistance of nonlinear cell/element must grow/rise with an increase of signal and change according to the law

$$R_{\text{нел}} = \frac{SR_0 R_n e^{\frac{z-1}{a}}}{D_1 z} - R_0 - R_n. \quad (\text{II-69})$$

For the selection of nonlinear cell/element during the calculation of cascade/stage it is necessary to have a dependence of $R_{\text{нел}_c} = f(U_{\text{нел}_c})$, which can be found from the generalized dependence of $R_{\text{нел}} = \varphi(z_{\text{нел}})$, where

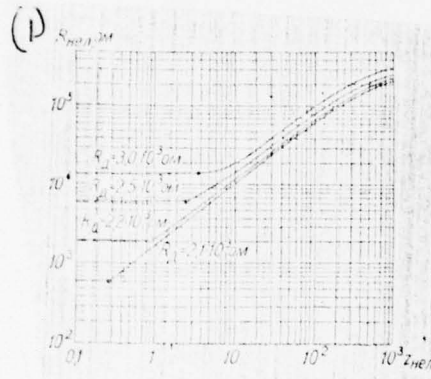
$$z_{\text{нел}} = \frac{U_{\text{нел}_c}}{U_{\text{вх}_1}} = z \frac{R_{\text{нел}_c}}{R_d}$$

and

$$U_{\text{нел}_c} = U_{\text{вх}} \frac{R_{\text{нел}_c}}{R_d}.$$

Fig. 26. Curved changes in the resistance of the nonlinear cell/element, which enters the composition of 2nd type divider/denominator.

Key: (1) ohm.



Substituting equation (II-69) in expression for an z_{neq} , we obtain

$$z_{\text{neqII}} = \left(\frac{SP_0 e^{\frac{a}{a}}}{zD_1} - \frac{R_0}{R_A} - 1 \right) z. \quad (\text{II-70})$$

Respectively in the work of cascade/stage in the quasi-linear mode/conditions:

$$R_{\text{neqIII}} = \frac{SP_0 R_A [z - a(\ln D_1 - 1) - 1]}{az} - R_0 - R_A, \quad (\text{II-71})$$

$$z_{\text{neqIII}} = \frac{SR_0}{a} [z - a(\ln D_1 - 1) - 1] - \left(\frac{R_0}{R_A} + 1 \right) z. \quad (\text{II-72})$$

Fig. 26 depicts curved $R_{\text{neq}} = \varphi(z_{\text{neq}})$, calculated from formulas (II-69) and (II-72) for the last/latter cascade/stage of five-stage amplifier from LAX. The calculation is produced for the case: $D_1 = K_1 = 10$; $R_p = 3 \cdot 10^4$ ohm; $S = 5.2$ mA/V; $a = 1$ at four values of the supplementary resistance of $R_A = 3 \cdot 10^3$ ohm; $2.5 \cdot 10^3$ ohm; $2.2 \cdot 10^3$ ohm; $2.1 \cdot 10^3$ ohm. From the figure one can see that the character of the curves of $R_{\text{neqc}} = \varphi(z_{\text{neq}})$ can be considerably changed by changing the value of the linear resistance of divider/denominator. The law of a change in the resistance of nonlinear cell/element [expression (II-69) and (II-71)] also largely depends on plate load E_0 and the value of the maximum factor of amplification k_1 , which is determined by the slope/transconductance of tube and by the resistances of R_0 , R_A and R_{neqI} . Thus, with the shunting of the plate load of cascade/stage by second type nonlinear divider/denominator are several paths of the izmkharaktera of the curves of $R_{\text{neqc}} = \varphi(z_{\text{neq}})$ or $R_{\text{neqc}} = f(U_{\text{neqc}})$.

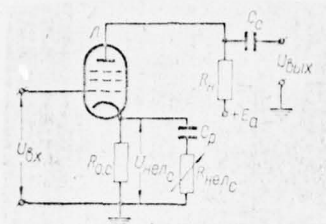


Fig. 27. The simplified circuit of cascade/stage with the nonlinear reverse/inverse svyaz'yuyu on alternating current. NP

§ 4. Application/use of a nonlinear feedback.

To regulate the factor of amplification of cascade/stage with an increase of signal possible with the aid of active nonlinear negative feedback on pyemennomu current or voltage.

Diagram with nonlinear current feedback.

The simplified circuit of cascade/stage with nonlinear negative feedback on alternating current is depicted on Fig. 27. Nonlinear feedback is realized by switching on in parallel to the resistance of the feedback of the $R_{0,c}$ of the nonlinear cell/element whose resistance $R_{ne,c}$ grow/rises with an increase by it of the voltage of the signal of $U_{ne,c}$. On constant component nonlinear cell/element is separated from cathode by the isolating capacitor of C_p . Amplification factor and output potential of nonlinear cascade/stage are respectively equal to:

$$K = \frac{SR_0}{1 + S\beta};$$

$$U_{BX} = U_{BX} \frac{SR_0}{1 + S\beta}, \quad (11-73)$$

where the $\rho = \frac{R_{o, c} R_{\text{нелс}}}{R_{o, c} + R_{\text{нелс}}}$ are the total resistance of feedback on alternating current.

The resistance of $R_{o, c}$ usually is undertaken by sufficiently large, the order of 3-6 kΩ. As nonlinear cell/elements also can be used vacuum or germanium semiconductor diodes of the type of DG-Q, D2 and D9, connected by the corresponding shape (Fig. 36).

Let us find the dependences on which must change the resistance of nonlinear cell/element from the applied to it voltage of signal.

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In the work of cascade/stage in linear conditions (amplification of low signals from 0 to U_{ex1}) the factor of amplification of cascade/stage must be the maximum and constant, i.e.,

$$K_1 = \frac{SR_0}{1 + S\rho_1} = \text{const}, \quad (11.74)$$

where

$$\rho_1 = \frac{R_{o, c} R_{\text{нелс1}}}{R_{o, c} + R_{\text{нелс1}}}. \quad (11.75)$$

For fulfilling this requirement the resistance of the nonlinear cell/element of $R_{\text{нелс1}}$ must be the minimum and constant. In the ideal

case the resistance of $R_{\text{нел}_1}$ must be equal to zero. Then $\rho_1 = 0$ and $K_{\text{I макс}} = SR_0$. Virtually always are fulfilled the inequalities of $R_{\text{нел}_1} > 0$ and $\rho_1 > 0$. Consequently, $\frac{K_1}{K_{\text{I макс}}} < 1$. The lesser the resistance of $R_{\text{нел}_1}$ and the mutual conductance of tube S, the nearer approaches unity the ratio/relation of the $\frac{K_1}{K_{\text{I макс}}}$.

The determination of the analytical expression of the law of a change of the nonlinear resistance of $R_{\text{нел}_c} = f(U_{\text{нел}_c})$ in the work of cascade/stage in logarithmic mode/conditions difficultly, since the very voltage of $U_{\text{нел}_c}$ depends on the value of the nonlinear resistance

$$U_{\text{нел}_c} = U_{\text{вх}} \frac{S_2}{1 + S_2} \quad (\text{II-76})$$

Solving together equations (II-3), (II-73) and (II-76), we obtain the complex transcendental equation which can be solved graphically. Much simpler separate to find analytical expressions for the dependence of $R_{\text{нел}_{II}} = f(U_{\text{вх}})$ and $U_{\text{нел}_c} = \varphi(U_{\text{вх}})$, a from them for each concrete/specific/actual case to graphically determine the dependence of the $R_{\text{нел}_{II}} = f(U_{\text{нел}_c})$.

Equating the right sides of the equation (II-3) and (II-73) and introducing the relative input voltage x , taking into account expression (II-74) we obtain

$$x \frac{SR_0}{1 + S_{\text{II}}} = \frac{SR_0}{1 + S_{\text{II}}} (a \ln x + 1),$$

whence

$$\rho_{11} = \frac{1}{S} \left(\frac{x(1+S\rho_1)}{a \ln x + 1} - 1 \right). \quad (II-77)$$

the $R_{\text{нел}11} = 0$

$$\rho_{11} = \frac{1}{S} \left[\frac{x}{a \ln x + 1} - 1 \right]. \quad (II-77a)$$

Substituting equation (II-77) in expression for ρ , we find the law according to which must change the resistance of nonlinear cell/element from x in the work of cascade/stage in the logarithmic mode/conditions

$$R_{\text{нел}11} = \frac{R_{o.c} \rho_{11}}{R_{o.c} - \rho_{11}} = \frac{\frac{x(1+S\rho_1)}{a \ln x + 1} - 1}{S - \frac{1}{R_{o.c}} \left[\frac{x(1+S\rho_1)}{a \ln x + 1} - 1 \right]}. \quad (II-78)$$

Expression (II-76) it is possible to record

$$x_{\text{нел}} = x \frac{S\rho}{1+S\rho}, \quad (II-79)$$

where the $x_{\text{нел}} = \frac{U_{\text{нел}c}}{U_{\text{BX}}}$ - the relative voltage of signal on nonlinear cell/element.

Substituting expression (II-77) in equation (II-79), we obtain

$$x_{\text{нел}11} = \frac{x(1+S\rho_1) - a \ln x - 1}{1+S\rho_1}. \quad (II-80)$$

In this case

$$U_{\text{нел}} = x_{\text{нел}} U_{\text{вх}}, \quad (\text{II-81})$$

With the $R_{\text{нел}} = 0$

$$x_{\text{нел}} = x - a \ln x - 1.$$

Let us find the appropriate expressions for an $R_{\text{нел}} = f(x)$ and $x_{\text{нел}} = \varphi(x)$ at the work of nonlinear cascade/stage in quasi-linear mode/conditions. Equating the right sides of the equations (II-21) and (II-73) and introducing relative input voltage, we obtain

$$\frac{x}{1 + S_{\text{нел}}} = \frac{1}{1 + S_{\text{нел}}} \left[a \ln D_1 + 1 - a + a \frac{x}{D_1} \right],$$

whence

$$\rho_{\text{нел}} = \left[\frac{x(1 + S_{\text{нел}})}{a \left(\ln D_1 + \frac{x}{D_1} - 1 \right) + 1} - 1 \right]. \quad (\text{II-82})$$

Page 58. Substituting equation (II-82) in expression for ρ , we find

$$R_{\text{нел}} = \frac{\frac{x(1 + S_{\text{нел}})}{a \left(\ln D_1 + \frac{x}{D_1} - 1 \right) + 1} - 1}{S - \frac{1}{R_{\text{о.с}}} \left[\frac{x(1 + S_{\text{нел}})}{a \left(\ln D_1 + \frac{x}{D_1} - 1 \right) + 1} - 1 \right]}. \quad (\text{II-83})$$

After the substitution of expression (II-82) into equation (II-79) we obtain

$$x_{\text{нел}} = \frac{x(1 + S_{\text{нел}}) - a \left(\ln D_1 + \frac{x}{D_1} - 1 \right) - 1}{1 + S_{\text{нел}}}. \quad (\text{II-84})$$

In this case,

$$U_{\text{нелII}} = x_{\text{нелII}} U_{\text{нхI}}, \quad (\text{II-85})$$

From expressions (II-78) and (II-83) it is evident that upon the inclusion of nonlinear cell/element into the cathode circuit of cascade/stage the law of a change in its resistance depends on slope/transconductance S , i.e., on the type of tube, value of the resistance of the feedback of $R_{o.c}$, which shunts nonlinear cell/element, furthermore, depends on the value of the initial total resistance of feedback ρ_1 , i.e., on the value of the initial resistance of the nelineynogo cell/element of $R_{\text{нелI}}$, which in turn, depends on the stress level of mixing on nonlinear cell/element. Thus, in this case are three degrees of freedom in a change in the law of the $R_{\text{нелII, III}} = f(x)$.

The dependence of $R_{\text{нелII, III}} = f(U_{\text{нелc}})$ they calculate in the following order. First they determine and are constructed the curve/graphs of $R_{\text{нелII, III}} = f(x)$ and $x_{\text{нелII, III}} = \varphi(x)$. Then on these curve/graphs plot a curve $R_{\text{нелII, III}} = \eta(x_{\text{нелI}})$, which utilizes for the plotting of curves of $R_{\text{нелII, III}} = f(U_{\text{нелc}})$ at the different values of the $U_{\text{нхI}}$.

In Fig. 28 are depicted curved $R_{\text{нелII}} = f(x)$ and an $x_{\text{нелII}} = \varphi(x)$, calculated from formulas (II-78) and (II-80), for case of $a = 1$; $\rho_1 = 100 \text{ ohm}$; $S = 5.2 \text{ mA/V}$; $R_{o.c} = 3,4$ and 5 comas .

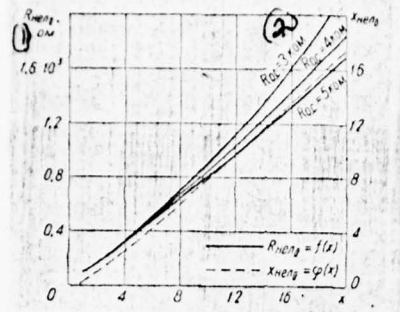


Fig. 28. Curved $R_{нелII} = f(x)$ and $x_{нелII} = \varphi(x)$ for the logarithmic section of the amplitude characteristic of cascade/stage.

Key: (1) ohm. (2) comas.

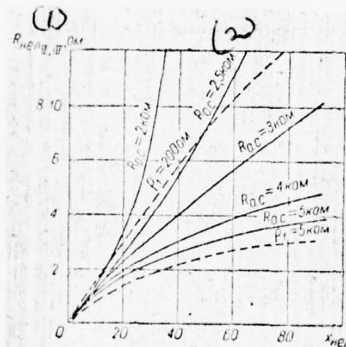


Fig. 29. Curved changes in the resistance of $R_{нелII, III} = f(x_{нелII})$:

— $\rho_1 = \text{const}; R_{0, c} = \text{var};$
 - - - $R_{0, c} = \text{const}; \rho_1 = \text{var}.$

Key: (1) ohm. (2) comas.

Figure 29 depicts curved $R_{\text{нелл, III}} = f(x_{\text{нел}})$, calculated and constructed for the different values of the resistance of aaaaa at the constant value of resistance $\rho_1 = 100 \text{ ohm}$ (unbroken curves), and also for the different values of resistance ρ_1 at the constant value of the resistance of the $R_{0,c} = 4$ of comas (dashed curves). During the calculation of curves, it is accepted: $a = 1$; $S = 5.2 \text{ mA/V}$; $D_1 = K_1$ 10 or $D_1 = 20 \text{ dB}$. value x varied from 1 to 100, which corresponds to the operating mode of the last/latter linear cascade/stage of five-stage logarithmic amplifier during a change in the entry stress of amplifier in the logarithmic range $D = 5 D_1$.

Figure 29 shows, that the greater the resistance of $R_{0,c}$ with the facts within limit inferiors must change the resistance of nonlinear cell/element with those very limits of a change in the signal. From the viewpoint of the provision for the necessary limit of a change in the resistance of nonlinear cell/element, it is expedient to undertake the the largest possible resistance of $R_{0,c}$. The requirement for the high resistance of $R_{0,c}$ especially pronounces with coefficient of $a < 1$, i.e., when the logarithmic operation of the stress in cascade/stage it is conducted with the foundation, greater than Naparian base. With $a < 1$, required limits of a change in the resistance of the nonlinear cell/element of $R_{\text{нелл, III}}$ will be considerably greater than this shown in Fig. 29.

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But too high a resistance of $R_{0,c}$ to undertake is inexpedient, since

on it will be separate/liberated high direct/constant voltage because of the course of the feed current of tube, which will lead to the need of applying of anode power supply with high stresses. Especially this phenomenon is perceptible when using tubes with a large slope/transconductance of the type of 6J9P, 6J20P, 6J11P, 6J21P which have large anode current.

The diagram in question makes it possible to carry out a strictly successive work of nonlinear cascade/stages and to obtain the LAX of the n-cascade amplifier of high accuracy.

Diagram with nonlinear voltage feedback.

The simplified circuit of cascade/stage with nonlinear negative voltage feedback is depicted on Fig. 30. During the fulfillment of the inequalities of $R_{\text{neg}} + R'_c \gg R_H$ and $R_i \gg R_H$ the factor of amplification of the cascade/stage

$$K_{\text{d.c.}} = \frac{K_1}{1 + \beta K_1}, \quad (11-86)$$

where the $\beta = \frac{R'_c}{R_{\text{neg}} + R'_c}$ - the transmission factor of feedback loop, which for the sake of simplicity in the analysis we consider real;

$$\frac{1}{R'_c} = \frac{1}{R_c} + \frac{1}{R_r} + \frac{1}{R_{\text{HX}}};$$

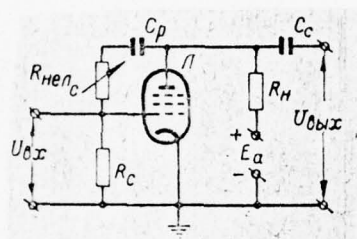
R_r are an internal impedance of the source of signal; $K_1 = SB_0$ - the maximum factor of amplification of cascade/stage in the absence of negative feedback, i.e., when $R_{\text{neg}} = \infty$ and $\beta = 0$.

output potential of the cascade/stage

$$U_{\text{out}} = U_{\text{in}} \frac{K_1 (R_{\text{нел}} + R_c')}{R_{\text{нел}} + R_c' + K_1 R_c'} \quad (11-87)$$

Let us find the law governing a change in the impedance of nonlinear cell/element, required for providing a successive work of nonlinear cascade/stages.

Fig. 30. The simplified circuit of cascade/stage with nonlinear voltage feedback.



During the amplification of low signals, i.e., in the work of cascade/stage in linear conditions, the feedback must not be $\beta = 0$. This is possible, if the impedance of $R_{\text{нелс}}$ greatly approaches infinity.

Utilizing expressions (II-3) and (II-87), in a known manner we find the dependence of $R_{\text{нелл}} = f(z)$ in the work of cascade/stage in the logarithmic mode/conditions

$$R_{\text{нелл}} = R_c' \left(\frac{D_1 \frac{z-1}{a} - 1}{\frac{e}{z} - 1} \right), \quad (\text{II-88})$$

since $K_1 = D_1$.

For the calculation of cascade/stage, is required the dependence of $R_{\text{нелс}} = \varphi(z_{\text{нел}})$. In this case

$$\begin{aligned} z_{\text{нел}} &= \frac{U_{\text{нелс}}}{U_{\text{вдх}}} = \\ &= \frac{z R_{\text{нелс}}}{R_{\text{нелс}} + R_c'}, \quad (\text{II-89}) \end{aligned}$$

since

$$U_{\text{нелс}} = \frac{U_{\text{вдх}}}{R_{\text{нелс}} + R_c'} R_{\text{нелс}}.$$

Substituting expression (II-88) in equation (II-89), we obtain

$$z_{\text{нелл}} = \frac{z \left(D_1 - \frac{e}{z} \frac{z-1}{a} + 1 \right)}{D_1}, \quad (\text{II-90})$$

In the work of nonlinear cascade/stage in the quasi-linear mode/conditions:

$$R_{ne\pi_{III}} = R'_c \left[\frac{\frac{D_1}{D_1(z - a \ln D_1 - 1 + a)} - 1}{az} \right]; \quad (II-91)$$

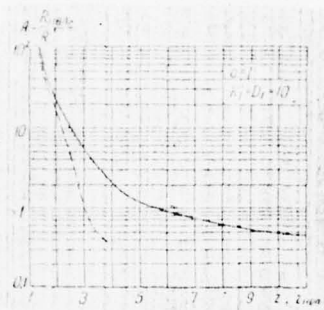
$$z_{ne\pi_{III}} = z \left[1 - \frac{z - a \ln D_1 - 1 + a}{az} + \frac{1}{D_1} \right] \quad (II-92)$$

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Fig. 31. Fig. 31. Given curved changes in the impedance of nonlinear cell/element in voltage feedback: $A = \bar{f}(z)$; $A = \bar{f}(z_{nc})$.



In order to calculate the dependence of the $R_{\text{neal}, III} = \varphi(z_{\text{neal}})$, it is necessary to preliminarily calculate from formulas (II-88), (II-90), (II-91) and (II-92) and to construct curved $R_{\text{neal}, c} = f(z)$ and $z_{\text{neal}} = \theta(z)$, from which then are constructed curved $R_{\text{neal}, c} = \varphi(z_{\text{neal}})$. Figure 31 depicts curved $\frac{R_{\text{neal}, c}}{R'_c} = f(z)$ (unbroken curve) and the $\frac{R_{\text{neal}, c}}{R'_c} = \varphi(z_{\text{neal}})$ (dashed curve), calculated from the indicated procedure for case of $a = 1$; $K_1 = D_1 = 10$. The calculation is produced for the last/latter cascade/stage of five-stage logarithmic amplifier. From expressions (II-88) and (II-91) it is evident that the character of the curve of $R_{\text{neal}, c} = \varphi(z_{\text{neal}})$ can be changed by changing the value of the impedance of R'_c . Curves, given in Fig. 31, it is possible to utilize during the calculation of the amplifier from LAX, which amplifies signals according to the law of natural logarithm. For this, the ordinates of the curve of $\frac{R_{\text{neal}, c}}{R'_c} = \varphi(z_{\text{neal}})$ must be multiplied by the rated value of the impedance of R'_c .

§ 5. Requirements for nonlinear cell/elements. Calculation of the entry impedance of nonlinear cell/element.

The requirements, pred'yavlyaemye to nonlinear cell/elements, can be divided into common/general/total, those which not depend on circuit solution, and quotients, determined by circuit solution. The general requirements include the following:

1) the static characteristics of the nonlinear cell/elements, connected in the different cascade/stages of n-cascade amplifier, they must be identical, i.e., nonlinear cell/elements must have small

spread of parameth;

2) the parameters of nonlinear cell/elements must be stable in time and during a change in the ambient temperature;

3) nonlinear cell/elements they must have small interelectrode capacitances, that especially importantly during the creation of broadband logarithmic amplifiers;

4) nonlinear cell/elements they must have high reliability;

5) nonlinear cell/elements they must have small overall sizes, a weight and a cost.

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The first requirement is provided by the preliminary selection of nonlinear cell/elements. The procedure for the selection of nonlinear cell/elements during the different circuit solutions of obtaining IAX is somewhat is different and examined in the subsequent III and IV chapters during the analysis of one or the other concrete/specific/actual diagram of logarithmic amplifier.

Requirement the stabilities of the parameters in time in the greatest measure satisfy the semiconductor diodes which in comparison with vacuum have considerably larger service life. The requirement

for the stability of the parameters during a change in the ambient temperature, on the contrary, in larger degree satisfy vacuum-tube diodes. From semiconductor diodes this requirement in the greatest measure satisfy silicon semiconductor diodes of the type of D101, D102, D101A, D102A etc., which have the maximum operating temperature to 150°C. From this viewpoint, they are most promising of all types of semiconductor diodes.

The third, fourth and fifth requirements to larger degree satisfy semiconductor diodes.

Let us examine the particular requirements, determined by concrete/specific/actual circuit solutions.

Requirements, imposed for nonlinear cell/elements with the polucheni of LAX by means of the shunting of the plate load of cascade/stage only by nonlinear cell/element, by first type nonlinear divider/denominator and when using nonlinear voltage feedback. In the enumerated three cases of circuit solution to nonlinear cell/elements, is presented one general requirement, namely: the impedance of nonlinear cell/element with low signals must be greatly, and with an increase in the signal - must decrease.

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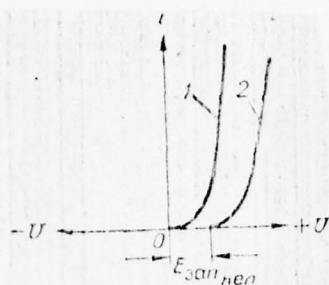


Fig. 32. The static characteristics of the nonlinear cell/element: 1 - without cutoff voltage; 2 - with cutoff voltage.

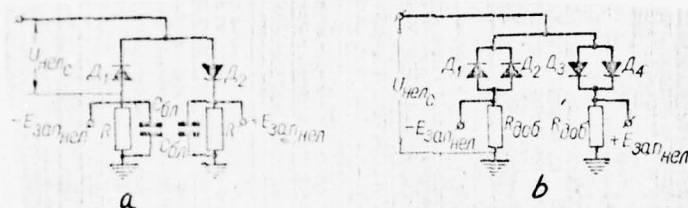


Fig. 33. Switchings on of nonlinear cell/elements with the shunting of the plate load of cascade/stage.

In this case, for providing a successive work of cascade/stages, nonlinear cell/element must satisfy the following requirements:

1. In the work of cascade/stage in linear conditions the impedance of nonlinear cell/element must be greatly and constantly to the value of voltage on it

$$U_{\text{нел.ц.}} = U_{\text{вх1}} = U_{\text{вх1}} K_1.$$

For fulfilling this requirement nonlinear cell/element it must have sharp current cutoff with the voltage on it of $U_{\text{вх1}}$, that it is possible to obtain by supply to the nonlinear cell/element of the cutoff voltage of the $E_{\text{зап.нел.}}$ of the numerically equal $U_{\text{вх1}}$.

Fig. 32 depicts the static characteristics of semiconductor diode without cutoff voltage (is curve 1) and with that which lock (is curve 2). Figure 33, a and b shows the circuit solutions of the supply of the cutoff voltage of $E_{\text{зап.нел.}}$ in the case of the amplification of harmonic oscillations. The diode D_1 in Fig. 33a is worker for the negative half-wave of voltage, diode D_2 it is for a positive half-wave. In the case of the amplification of video pulses, is included one diode.

2. In the work of cascade/stage in logarithmic mode/conditions, the impedance of nonlinear cell/element must change according to the law, expressed with formula (II-60) either (II-64) in the case of the shunting of plate load by nonlinear cell/element (first type nonlinear divider/denominator) or on (II-88) in the case of applying nonlinear

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voltage feedback.

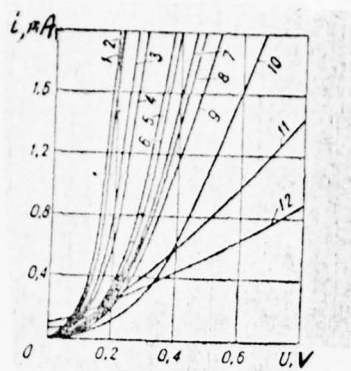


Fig. 34. The volt-amperes characteristic of the different nonlinear cell/elements: 1 - D202; 2 - D203; 3 - DG-Q21; 4 - D2A; 5 - D2E; 6 - DG-Q8; 7 - D2J; 8 - DG-Q4; 9 - L1D; 10 - 6NZF (with diode switching on); 11 - 6X2P; 12 - 6X6S.

For fulfilling this requirement, it is necessary that the nonlinear section of the volt-ampere characteristic of nonlinear cell/element, which ensures LAX of cascade/stage, would stretch from the voltage of $U_{\text{нелс}_1} = U_{\text{вх}_1}$ to the voltage of $U_{\text{нелс}_2} = U_{\text{вх}_2} = U_{\text{вх}_1} (a \ln D + 1)$ in the first two cases and from the voltage of $U_{\text{вх}_1}$ to the voltage

$$U'_{\text{нелс}_2} = U_{\text{вх}_1} \frac{(a \ln D_1 + 1) \left(D_1 - \frac{D_1 e^{\frac{1}{a}}}{a \ln D_1 + 1} + 1 \right)}{D_1} \quad (\text{II-93})$$

in the third case.

3. In the work of the i nonlinear cascade/stage in quasi-linear mode/conditions the impedance of nonlinear cell/element in the first two cases must change according to the law (II-61) either (II-65) during a change in the voltage of signal on it from $U_{\text{нелс}_1}$ to

$U_{\text{нелс}_2} = U_{\text{вх}_1} (i a \ln D + 1)$ or according to the law (II-91) in the third case during a change in the voltage of signal on it from $U_{\text{нелс}_1}$ to

$$U'_{\text{нелс}_2} = U_{\text{вх}_1} (i a \ln D_1 + 1) \left(1 - \frac{(i-1) \ln D_1 + 1}{i a \ln D_1 + 1} + \frac{1}{D_1} \right). \quad (\text{II-94})$$

Fig. 34 depicts the volt-amperes characteristic of some nonlinear cell/elements. one of the requirements, imposed to static characteristic, is the presence in the beginning of the characteristic of the sharply pronounced nonlinear section with large slope/transconductance, which gradually passes over to linear. Most adequate from this viewpoint are the germanium semiconductor diodes of the type of DGQ1DGQ10, D2A-D2J, D9A-D9J and the silicon semiconductor

diodes of the type of D101, D102, D101A etc.

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It should be noted that in the slope/transconductance of the initial nonlinear section the characteristics of diodes of the type D9 approach characteristics of diodes of the type of D202. Silicon diodes of the type of D101 and D102 have very small mutual conductance in the initial section to voltages 0.1-0.2 in; with high voltages the mutual conductance sharply grow/rises.

Diodes of the type of D202 and DG-Q21 - DG-Q23 have very large mutual conductance in the initial section, but are unsuitable as a result of the large stray capacitance which reaches 50 pF. Double diodes of the type of 6X6 and miniature/small diodes of the type of 6X2P are unsuitable as a result of the weakly expressed nonlinear section in the beginning of static characteristic and small slope/transconductance on nonlinear section. Tubes of the type of 6N3P and 6N15P in diode switching on have somewhat better/best indices, than the diodes of 6X6 and 6X2P, but they all the same from their parameters are inferior to germanium and silicon semiconductor diodes.

The application/use of semiconductor diodes as nonlinear cell/elements in comparison with double diodes and the tubes, utilized as diodes, most is rational both in the structural/design relation and

in the relation to the introduced capacitance/capacity, which is especially important in designing wideband amplifiers.

Requirements, imposed for nonlinear cell/elements in obtaining LAX by means of the shunting of plate load by second type nonlinear divider/denominator and when using a current feedback.

In these cases of circuit solution to nonlinear cell/elements, is presented one general requirement, namely: the impedance of nonlinear cell/element with low signals must be little, and with an increase in the signal - must grow/rise. As nonlinear cell/elements it is possible to utilize germanium semiconductor diodes of the type of 2G-Q, D2, D9 and silicon diodes of the type of D101, D102 etc. In order that the impedance of diode would grow/rise with an increase of the applied to it voltage of signal, it is necessary diodes to switch on on the scheme of Fig. 35 in the case of the amplification of video pulses and by diagram in Fig. 36 in the case of the amplification of sinusoidal oscillations. Impedance R is included in order that the source of bias voltage would not shunt nonlinear cell/element.

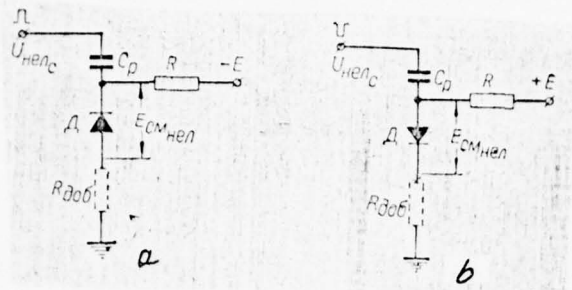


Fig. 35. Inclusions of nonlinear cell/elements in the diagram of amplification with feedback on current for the video pulses: a) positive; b) negative.

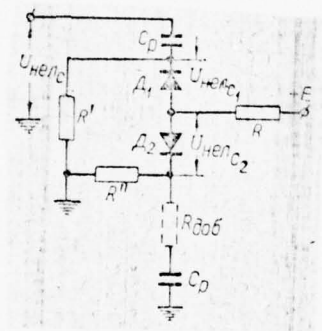


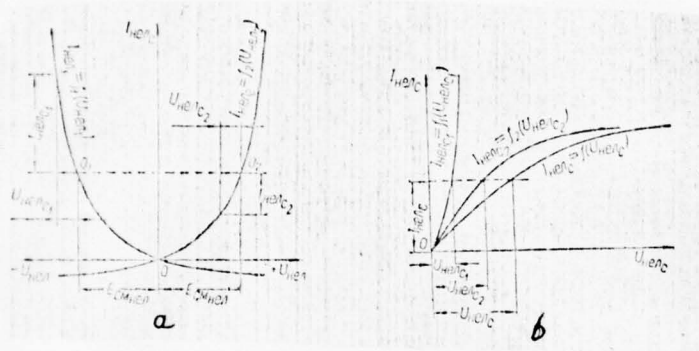
Fig. 36. Inclusion of nonlinear cell/elements in the diagram of the amplification of radio pulses with feedback on current.

On impedances R' and R'' flow/lasts direct current and thereby it is created bias voltage on nonlinear cell/elements D_1 and D_2 . The supplementary impedance of $R_{доб}$ sometimes is connected for a change in the dynamic volt-ampere characteristic of nonlinear cell/element.

Let us examine the work of the nonlinear cell/elements, connected by diagram in Fig. 36. To diodes D_1 and D_2 , is supplied the positive constant bias voltage of $E_{см\text{пол}}$. If diodes are include/connected by reversed polarities, then on them it is necessary to supply negative bias voltage. In this case, the effect will be obtained such, as in the case of the supply of the positive voltage of the $E_{см\text{пол}}$.

During the supplying of the voltage of $E_{см\text{пол}}$ operating point O_1 on the static volt-ampere characteristic of diode D_1 is displaced to the left, while to the that of diode D_2 it is displaced to the right (Fig. 37a). With identical diodes D_1 and D_2 , the displacement of operating points O_1 and O_2 is equal.

Fig. 37. Graphic construction of the dynamic volt-ampere characteristic of nonlinear cell/element.



For the positive half-wave of the signal of the aaaaa of that being isolated on nonlinear cell/elements, as working nonlinear cell/element serves the diode D_1 , while for the negative half-wave of signal, it serves diode D_2 . In the case of the amplification of video pulses, is utilized the only one diode and to examine necessary only one of the static characteristics, depicted on Fig. 37a. With identical nonlinear cell/elements dynamic volt-amperes characteristic for both cell/elements are identical and have a form, depicted on Fig. 37b.

The dynamic volt-ampere characteristic of nonlinear cell/element let us agree to call the dependence of the value of the prompt current of the $I_{\text{нелс}} = f(U_{\text{нелс}})$, of that taking place through the nonlinear cell/element, from the stress level of the signal of the $U_{\text{нелс}}$, of that applied to nonlinear cell/element. This form of dynamic characteristic at the low values of the voltage of $U_{\text{нелс}}$ causes the low values of the impedance of the nonlinear cell/element of $R_{\text{нелс}}$, a at great significance of $U_{\text{нелс}}$ - great significance of the $R_{\text{нелс}}$.

In the case of the shunting of the plate load of cascade/stage by second type nonlinear divider/denominator for the realization of the strictly successive work of cascade/stages nonlinear cell/element must satisfy the following requirements:

1. In the work of cascade/stage in linear conditions, the impedance of nonlinear cell/element must be constant and equal to the value, determined by expression (II-68), during a change in the voltage of signal on nonlinear cell/element from 0 to

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$$U_{\text{нел}c_1} = U_{\text{внх}_1} \left(\frac{SR_0}{K_1} - \frac{R_0}{R_A} - 1 \right). \quad (\text{II-95})$$

2. In the work of cascade/stage in logarithmic mode/conditions, the impedance of nonlinear cell/element must change according to the law, found by graphic plotting of curves (II-69) and (II-70). The voltage of signal on nonlinear cell/element varies from $U_{\text{нел}c_1}$ to

$$U_{\text{нел}c_2} = U_{\text{внх}_1} (a \ln D_1 + 1) \left(\frac{SR_0}{a \ln D_1 + 1} - \frac{R_0}{R_A} - 1 \right). \quad (\text{II-96})$$

3. In the work of the i cascade/stage in quasi-linear mode/conditions, the impedance of nonlinear cell/element must change on the sakonu, found by consistent plotting of curves (II-71) and (II-72). The voltage of signal on nonlinear cell/element varies from $U_{\text{нел}c_i}$ to

$$U_{\text{нел}c_i} = U_{\text{внх}_1} (i a \ln D_1 + 1) \times \left\{ \frac{SR_0 [(i-1) \ln D_1 + 1]}{i a \ln D_1 + 1} - \frac{R_0}{R_A} - 1 \right\}. \quad (\text{II-97})$$

The nonlinear cell/element, the back-out resistor of feedback in cathode circuit, for obtaining the amplitude characteristic of cascade/stage, which ensures the strictly successive work of the cascade/stages of n -cascade amplifier, it must satisfy the following requirements:

1. In the work of cascade/stage in linear conditions, the impedance of nonlinear cascade/stage must be little and constantly to the value of the voltage of signal on it

$$U_{\text{нелс}_1} = x_{\text{нел}_1} U_{\text{вх}_1} = U_{\text{вх}_1} \frac{S_{\rho_1}}{1 + S_{\rho_1}},$$

in order that the common initial impedance of feedback ρ_1 would be minimum and constant, but the factor of amplification of cascade/stage was maximum and constant. For fulfilling this requirement nonlinear cell/element to dolzhenimet' rectilinear dynamic volt-ampere characteristic with large slope/transconductance on the section of a change in the voltage of signal on it from 0 to the $U_{\text{нелс}_1}$.

2. In the work of cascade/stage in logarithmic mode/conditions, the impedance of nonlinear cell/element must change according to the law, found by graphic plotting of curves (II-78) and (II-80).

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The voltage of signal on nonlinear cell/element varies from $U_{\text{нелс}_1}$ to

$$U_{\text{нелс}_2} = U_{\text{вх}_1} \frac{D_1 (1 + S_{\rho_1}) - a \ln D_1 - 1}{1 + S_{\rho_1}}. \quad (\text{II-98})$$

3. In the work of the i cascade/stage in quasi-linear mode/conditions, the impedance of nonlinear cell/element must change according to the law, found by consistent plotting of curves (II-83) and (II-84). The voltage of signal on nonlinear cell/element changes from the voltage of $U_{\text{нелс}_2}$ to

$$U_{\text{нелс}} = U_{\text{вх}} \left\{ D_1 [(i-1) a \ln D_1 + 1] - \frac{a \ln D_1 + 1 - a + \frac{D_1 [(i-1) a \ln D_1 + 1]}{L_1}}{1 - S_{p1}} \right\} \quad (\text{II-99})$$

For fulfilling the first and second requirements necessary that the dynamic volt-ampere characteristic of nonlinear cell/element during an increase on it in the voltage of signal sharply would differ from the axis of ordinates. The slope/transconductance of the deviation of characteristic it depends on the value of the impedance of $R_{\text{вх}}$ and must to be the more greater, the less this impedance.

Calculation of the entry impedance of nonlinear cell/element.

Under the entry impedance of nonlinear cell/element (semiconductor or vacuum-tube diode) in the case of resonance system and sinusoidal oscillations, one should understand the ratio of the amplitude of the applied voltage of U_m to the amplitude of the current of the fundamental harmonic of the I_{m1} .

$$R_{\text{вх}} = R_{\text{нелс}} = \frac{U_m}{I_{m1}} \quad (\text{II-100})$$

The entry impedance of nonlinear cell/element in the case of aperiodic system can be determined from the formula

$$R_{\text{вх}} = R_{\text{нелс}} = \frac{U_{\text{нелс}}}{I_{\text{нелс}}}, \quad (\text{II-101})$$

where the $U_{\text{нелс}}$ is amplitude of sine voltage during sinusoidal

oscillations or the amplitude of the video pulse of voltage during the amplification of video pulses;

$I_{\text{нелс}}$ the amplitude of the current, which takes place through the nonlinear cell/element (Fig. 37a).

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The amplitude of the fundamental harmonic of the current, which takes place through the nonlinear cell/element, connected by diagram in Fig. 33, it is possible to determine by the static volt-ampere characteristic of cell/element, which it is possible to find in handbook or to remove/take it is experimental. If nonlinear cell/elements are included by diagram in Fig. 35, then the amplitude of the fundamental harmonic of the current, which takes place through the cell/element, can be found only from the dynamic volt-ampere characteristic of this cell/element, but if by diagram in Fig. 36, then - according to the dynamic characteristic of equivalent nonlinear cell/element. Equivalent nonlinear cell/element let us agree to call the cell/element, which consists of two diodes D_1 and D_2 , connected in series and contrarily on polarity (Fig. 36). Impedances R' and R'' are selected by sufficiently large (dozen kilohm) and in effect do not affect dynamic characteristics. It should be noted that with the $U_{\text{нелс}}$, considerable voltages of $R_{\text{нелс}}$ when the impedance of the diode of aaaa greatly composes hundred kilohm, to dynamic characteristic to a certain degree, affects impedance R' . But since impedance R' included

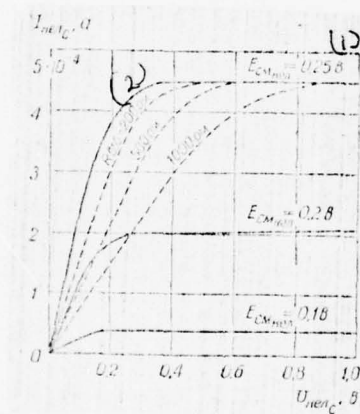
in parallel to the impedance of the feedback of $R_{o.c}$ (see Fig. 27) and usually is made the inequality of $R' \gg R_{o.c}$, that by the effect of impedance R' on the dynamic characteristic of equivalent nonlinear cell/element it is possible to disregard.

The procedure for the construction of the dynamic volt-ampere characteristic of the $I_{нел.c} = f(U_{нел.c})$ of the equivalent nonlinear cell/element, which consists of two diodes, is shown in Fig. 37.

Let us examine this procedure. First are constructed the static volt-amperes characteristic of diodes D_1 and D_2 (Fig. 37a). Then for this value of the voltage of $E_{с.м.нел.}$ being given the values of the voltage of the signal of identical polarity on separate/individual diodes, are constructed the dynamic characteristics of $I_{нел.c_1} = f_1(U_{нел.c_1})$ and $I_{нел.c_2} = f_2(U_{нел.c_2})$ for diodes D_1 and D_2 .

Fig. 38. Dynamic volt-amperes characteristic of equivalent nonlinear cell/element.

Key: (1). V. (2) ohm.



The dynamic characteristic of equivalent nonlinear cell/element is constructed according to the dynamic characteristics of diodes by the method of the combined ordinates whose essence briefly entails the following. Since the diodes D_1 and D_2 are connected in series, for each value of the current of the $I_{\text{нелс}}$, of that taking place through both diodes, summarize the corresponding voltage drops of $U_{\text{нелс}_1}$ and $U_{\text{нелс}_2}$ and construct the resulting characteristic of $I_{\text{нелс}} = f(U_{\text{нелс}}) = f(U_{\text{нелс}_1} + U_{\text{нелс}_2})$ (Fig. 37b). If the diodes D_1 and D_2 are identical, then the dynamic characteristic of equivalent nonlinear cell/element will be identical both for the positive signal and for negative.

Figure as 38 solid lines depicts the dynamic volt-amperes characteristic of the equivalent nonlinear cell/element, which consists of two series-connected diodes of the type of D2J. Characteristics are constructed according to the procedure presented. From the figure one can see that with an increase in the bias voltage on nonlinear cell/element the slope/transconductance of the initial section of characteristic grow/rises. In this case, the initial impedance of the cell/element of $R_{\text{нелс}}$ with small voltages of $U_{\text{нелс}}$ decreases. The form of dynamic characteristic can be changed with connection consecutively with the nonlinear cell/element of the supplementary active linear impedance of $R_{\text{доб}}$. Figure as 38 broken lines depicts the dynamic characteristics of equivalent nonlinear cell/element at three values of the supplementary impedance of $R_{\text{доб}} = 200, 500, 1000$ ohm and with the bias voltage of $E_{\text{смнел}} = 0,25$ in.

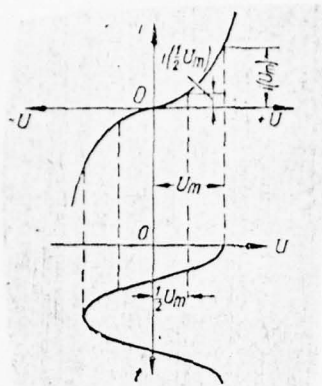


Fig. 39. Procedure for the determination of components from the method five ordinates with the symmetrical volt-ampere characteristic of nonlinear cell/element.

Upon the switching on of the impedance of $R_{\text{доб}}$ increases the initial impedance of equivalent nonlinear cell/element, which, in turn, leads to a decrease in the maximum factor of amplification of cascade/stage.

Both static and dynamic the characteristics of nonlinear cell/element can be assigned either graphically or analytically. If characteristic is assigned graphically, then the amplitude of the current of fundamental harmonic can be determined graphically by method of five [12] or twelve of ordinates. These methods are very simple and give the accuracy of the determination of the I_{m_1} of order 5-8c/o. By using the method five ordinates, the amplitude of the fundamental harmonic of the current, which takes place through the nonlinear cell/element, can be determined by the formula

$$I_{m_1} = \frac{2}{3} \left[i(U_m) + i\left(\frac{1}{2} U_m\right) \right], \quad (\text{II-102})$$

where the $i(U_m)$ и $i\left(\frac{1}{2} U_m\right)$ - the value of current with the voltage, equal to the amplitude and the half of the amplitude of stress.

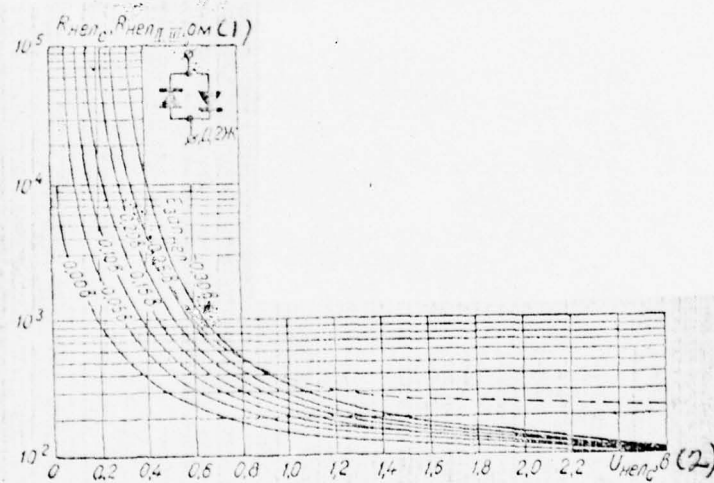
The procedure for the determination of the currents of $i(U_m)$ and $i\left(\frac{1}{2} U_m\right)$ with the symmetrical volt-ampere characteristic of nonlinear cell/element is shown in Fig. 39.

From formula (II-102) is determined the amplitude of the fundamental harmonic of current for the different values of the amplitude of applied voltage, and then according to formula (II-100) - the entry impedance of nonlinear cell/element is constructed the

dependence of $R_{bx} = R_{ne\eta_c} = \varphi(U_{ne\eta_c})$, where by $U_{ne\eta_c}$ necessary to understand the amplitude of the U_m .

In Fig. 40 are shown curved changes in the impedance of a germanium crystal diode of the type of D2J on the applied to it voltage of signal with the different cutoff voltages of $E_{зап\eta_{c\eta}}$ on it. Curves are designed by the method five ordinates.

Fig. 40. Curved changes in the impedance of a diode of the type of L2J with different cutoff voltages: — $R_{\text{незс}} = \varphi(U_{\text{незс}})$; - - - $R_{\text{незс}}, \Omega = f(U_{\text{незс}})$.



The character of the curves of $R_{\text{нел}} = \varphi(U_{\text{нел}})$ it is possible to change, connecting in parallel several diodes of identical polarity, either connecting in series with diode the linear effective resistance of $R_{\text{доп}}$ (see Fig. 33b) or including simultaneously in parallel and consecutively. The impedance of $R_{\text{доп}}$ it is expedient to spol'zovat' for the creation on it of the cutoff voltage of $E_{\text{зап.нел}}$. Figure 41 shows curved changes in the impedance of the $R_{\text{нел}}$ of one diode of the type of D2J (dash) and of two diodes (solid line) with different supplementary impedances with the cutoff voltage of $E_{\text{зап.нел}} = 0,1$ in.

It should be noted that the amount of diodes is indicated for the half-wave of the voltage of the signal of one polarity. For a sine voltage the amount of diodes two times is more, since it is necessary to ensure identical conductivity for both half-waves of the voltage of the $U_{\text{нел}}$.

During the supplying of cutoff voltage on nonlinear cell/element (diode) the parallel connection of several diodes, and also the switching on of the supplementary impedance of $R_{\text{доп}}$ it leads to the perceptible change of the curve of $R_{\text{нел}} = \varphi(U_{\text{нел}})$ only in the range of low impedances, i.e., in the zone of the high stresses of $U_{\text{нел}}$.

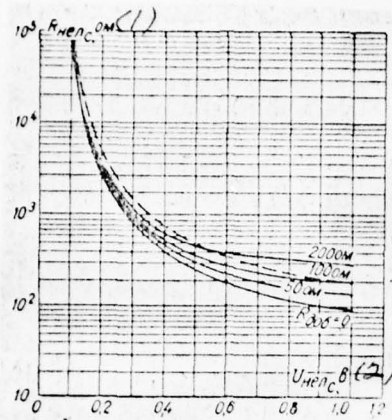


Fig. 41. Curved changes in the impedance of a diode of the type of D2J during the different supplementary impedance: ---- are one diode; the — of two diode; $E_{\text{зан.н.н}} = 0.1$ in.

Key: (1) ohm. (2) . V.

This allows by the variation of the number of in parallel connected diodes and value of the impedance of $R_{доб}$ to obtain a series of the curves of $R_{нелс} = \varphi(U_{нелс})$, sufficiently accurately approaching the required theoretical curve of $R_{нелл, III} = f(U_{нелс})$ for providing a successive work of nonlinear cascade/stages.

Figure 42 gives the curved changes in the impedance of $R_{нелс} = \varphi(U_{нелс})$ for two series-connected diodes of the type of D2J, calculated by the method five ordinates in the dynamic characteristics, depicted on Fig. 38.

Figures 28, 29 and 42 show that the law of a change in the impedance of the equivalent nonlinear cell/element of $R_{нелс} = \varphi(U_{нелс})$ sufficiently coincides precisely with the required law of $R_{нелл, III} = \eta(X_{нел})$ during the impedance of the feedback of the $R_{о.с} = 2,5 \div 3$ of comas.

The character of the curves of $R_{нелс} = \varphi(U_{нелс})$ it is possible to change, applying semiconductor germanium diodes of the type of D2A, D9A and the D9B, which have static volt-ampere characteristic with large slope/transconductance. In this case equivalent nonlinear cell/element with small stresses has low initial impedance, and with high stresses - large. Curved $R_{нелс} = \varphi(U_{нелс})$ pass more steeply than in Fig. 42. In this case, it is possible to obtain the sufficiently large factor of amplification of cascade/stage of work in linear conditions, that facilitates the selection of the necessary the curve $R_{нелс} = \varphi(U_{нелс})$.

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The graphic method of calculation of the entry impedance of nonlinear cell/element it can be applied with the large amplitudes of stresses.

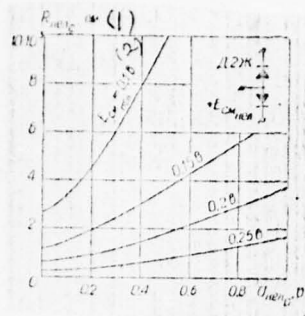


Fig. 42. Curved changes in the impedance of equivalent nonlinear cell/element with different bias voltages.

Key: (1) ohm. (2) V.

With small amplitudes of stresses graphic method it can lead to considerable errors; therefore the amplitude of the current of I_m expedient to determine analytically. For this, it is necessary to know the analytical expression of static characteristic.

The volt-ampere characteristic of nonlinear cell/element can be approximated by the following functions: by exponential $i = f(U) = i_0 e^{aU}$ or $i = i_0 (e^{aU} - 1)$; exponential $i = f(U) = AU^n$; by polynomial $i = f(U) = \alpha U + \beta U^2 + \gamma U^3 + \dots$; by the hyperbolic tangent $i = f(U) = i_m \tanh pU$.

By exponential function sufficiently accurately it is possible to approximate the characteristic of nonlinear cell/element only with small stresses on it. By the function of the form of $i = i_0 e^{aU}$ it is expedient to approximate the characteristic of vacuum-tube diode, while by the function of the form of $i = i_0 (e^{aU} - 1)$ - the characteristic of semiconductor diode. Most accurately the characteristic of nonlinear cell/element during a change in the stress on it within large limits can be approximated by exponential function. The approximation of characteristics with the aid of polynomial is obtained sufficiently precisely only with a comparatively large number of terms of polynomial. By hyperbolic tangent can be accurately approximated not all forms of the characteristics of nonlinear cell/elements.

Let us determine the amplitude of the fundamental harmonic of current in the case of application/use as the nonlinear cell/element of the vacuum-tube diode whose characteristic is approximated by the

exponential function of the form of $i = i_0 e^{aU}$. Let the plate-to-cathode voltage of diode change according to the law

$$U = -U_0 + U_m \cos \omega t,$$

where

$$U_0 = E_{\text{затяжка}}.$$

Then

$$i = i_0 e^{a(-U_0 + U_m \cos \omega t)} = i_0 e^{-aU_0} e^{aU_m \cos \omega t}.$$

Page 77. The factor of $e^{aU_m \cos \omega t}$ as a result of a change in the amplitude of applied voltage U is the function of the form of $e^{x \cos \omega t}$, which it is decompose/expanded in a series in the Bessel functions of the imaginary argument

$$e^{x \cos \omega t} = J_0(jx) + 2 \sum_{n=1}^{\infty} J_n(jx) \cos n\omega t,$$

then

$$i = i_0 e^{-aU_0} [J_0(jx) + 2 \sum_{n=1}^{\infty} J_n(jx) \cos n\omega t].$$

After sweeping this series, we will obtain

$$i = i_0 e^{-aU_0} J_0(jx) + 2j^{-1} i_0 e^{-aU_0} J_1(jx) \cos \omega t - 2i_0 e^{-aU_0} J_2(jx) \cos 2\omega t + \dots$$

By the amplitude of fundamental harmonic it is the coefficient of $\cos \omega t$, i.e.,

$$I_{m1} = 2j^{-1} i_0 e^{-aU_0} J_1(jx), \quad (11-103)$$

where $j^{-1} J_1(jx)$ - the modified Bessel function of first-order.

It is known that

$$J_n = j^{-1} J_n(jx) = \frac{\left(\frac{x}{2}\right)^n}{\Gamma(n+1)} + \frac{\left(\frac{x}{2}\right)^{n+2}}{\Gamma(n+2)} + \frac{\left(\frac{x}{2}\right)^{n+4}}{2! \Gamma(n+3)} + \dots$$

$$\dots + \frac{\left(\frac{x}{2}\right)^{2n}}{\left(\frac{n}{2}\right)! \Gamma(2n)}; \quad (\text{II-104})$$

$$j^{-1} J_1(jx) = \frac{x}{2} + \frac{\left(\frac{x}{2}\right)^3}{2} + \frac{\left(\frac{x}{2}\right)^5}{2 \cdot 3!} + \dots$$

After substituting expression (II-104) in (II-103) and after replacing x by aU_m , we will obtain

$$I_{m1} = i_0 e^{-aE_{320\text{вел}}} \left[aU_m + \frac{a^3 U_m^3}{2^3} + \frac{a^5 U_m^5}{3 \cdot 2^5} + \dots \right],$$

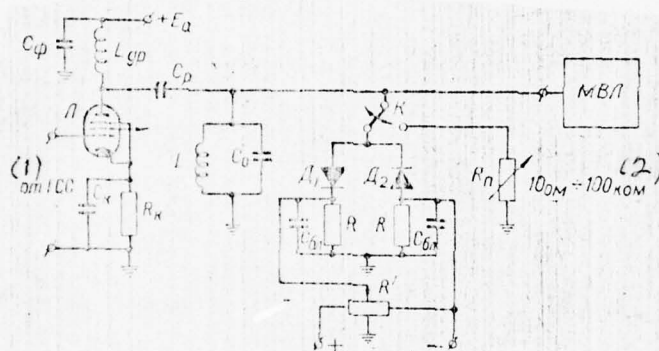
then the entry impedance of the diode

$$R_{\text{ввх}} = R_{\text{вх}} = \frac{U_m}{I_{m1}} =$$

$$= \frac{e^{aE_{320\text{вел}}}}{i_0 \left[a + \frac{a^3 U_m^2}{2^3} + \frac{a^5 U_m^4}{3 \cdot 2^5} + \dots \right]}. \quad (\text{II-105})$$

Fig. 43. Measuring circuit of the impedance of nonlinear cell/element according to substitution method.

Key: (1) ohm. (2) comas.



Page 78. Coefficients i_0 and a can be determined by the static characteristic of nonlinear cell/element with the aid of the method of least squares which is sufficiently minutely presented in N. N. Krylov's book [13], or with the aid of the method, described in L. S. Gutkin's book [9].

Formula (II-105) is suitable for the calculation of impedance only with small voltages of U_m . With the high voltages of U_m the characteristic of nonlinear cell/element must be approximated by exponential function, polynomial or hyperbolic tangent. In this case the amplitude of I_{m1} is determined from the formula

$$I_{m1} = \frac{2}{T} \int_0^T i(U) \cos \omega t. \quad (\text{II-106})$$

Curved $R_{EX} = R_{EXC}$ they can be removed experimentally according to substitution method. Installation diagram for relieving the curves of $R_{EXC} = \varphi(U_m)$ is depicted on Fig. 43. Amplifier tube in diagram is necessary for obtaining the high output resistance of the source of signal. Curves with the different cutoff voltages of $E_{зануел}$ on nonlinear cell/elements are remove/taken as follows. To the inlet of tube 1, is supplied the voltage of the determined value. With the aid of a millivoltmeter of the type of MVL-3 or MVL-4, is determined the edge stress LC_0 with the connected to it nonlinear cell/elements D_1 and D_2 . Then with the aid of key/wrench K in parallel to duct instead of the nonlinear cell/elements is connected the potentiometer of R_n . Changing the impedance of R_n , they attain previous reading millivoltmeter. In this case the value of the impedance of R_n is

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equal to the impedance of nonlinear cell/elements. Similarly are
remove/taken other points of the curve of $R_{\text{нел}} = \varphi(U_m) = \varphi(U_{\text{нел}})$.

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§ 6. Use of automatic gain control.

For obtaining LAX in n-cascade selective and aperiodic amplifiers by a change of the amplification factor or by the addition of voltages from the output/yields of cascade/stages successfully it can be applied by AGC.

In selective amplifiers and speech amplifiers AGC, it is realized as follows. The output voltage of separate cascade/stage or amplifier as a whole is detected and obtained thus direct/constant voltage is utilized for the control of displacement on the control electrodes of amplifier tubes. An increase in the output signal increases bias voltage on the grids of the controlled tubes and decreases their amplification. If we calculate network elements AGC by the determined shape, then it is possible to obtain the logarithmic dependence between the output and input voltage of amplifier. In this case, the dynamic range the LAX of amplifier is determined by the number of

adjustable cascade/stages.

It is possible in principle to carry out two form of systems AGC: system with feedback when the controlling voltage is supplied from the subsequent cascade/stages to preceding/previous (Fig. 44), and system without the feedback when the controlling voltage it is supplied from the preceding/previous cascade/stages to those which follow (Fig. 45).

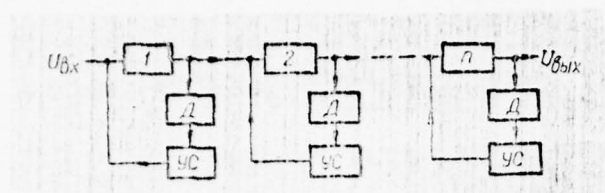


Fig. 44. System AGC with feedback.

Fig. 45. System AGC without feedback.

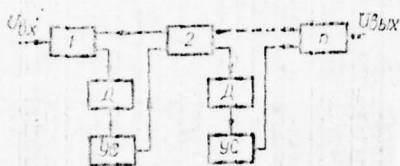


Fig. 45.

To RIs. 44 and 45 oboznaceno: 1, 2, ..., n - amplifier stages; d - detector AGC; U_s - amplifier in circuit AGC.

As detector can be used vacuum or semiconductor diode. In principle diode can no and the function of detection in this case fulfills amplifier tube. By changing the amplifier gain in circuit AGC, it is possible to obtain the various forms of the amplitude characteristic of cascade/stage. It is necessary to note that when using a system AGC with feedback the depth of the adjustment of amplifier stage cannot be obtained more than any determined value, i.e., the slope/inclination of the amplitude characteristic of cascade/stage with an increase in the factor of amplification k of amplifier in circuit AGC cannot be obtained the more than completely determined slope/inclination. In Fig. 46 numeral 1 designated the range (shaded), at which can lie/rest the amplitude characteristic of amplifier stage with AGC with feedback. With an increase in the amplifier gain, U_s in circuit AGC of $(K^I, K^{II}, K^{III}, K^{IV})$ the amplitude characteristic of cascade/stage approaches an axis of abscissas. But on the strength of the properties, inherent in control systems with feedback, the amplitude characteristic of cascade/stage cannot go lower than shaded range. Consequently, by applying system AGC with feedback, it is possible to obtain the amplitude characteristic of cascade/stage, which provides a precise LAX of cascade amplifier with the method of the addition of voltages only with coefficient of $a = 1$.

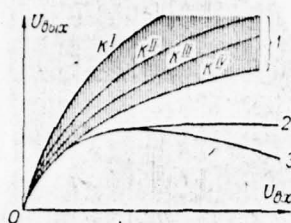


Fig. 46. Amplitude characteristics of amplifier with AGC.

But it is not possible to obtain the characteristic of cascade/stage, which satisfies the requirements for obtaining the LAX of amplifier with the method of consecutive addition with any coefficient of a (dashed curves in Fig. 13).

From this deficiency/lack is free the system AGC without the feedback applying which it is possible (changing amplification factor in circuit AGC) to obtain the amplitude characteristic of a cascade/stage of any type (RIs. 4, types 1, 2 3). This is explained by the fact that in the system AGC in question the amplifier in the circuit of adjustment is not encompassed by feedback.

In system AGC without feedback, the time constant of the function of system can be very small. Consequently, this system of gain control can be applied for obtaining LAX both in the video amplifiers and in the pulse tuned amplifiers, intended for the amplification of the momentum/impulse/pulses of short duration.

An essential deficiency/lack in the diagram AGC without feedback is the large criticality to the exchange of tubes and the large amplification in the circuit of adjustment.

In connection with this is most widely common the system AGC with feedback whose calculation is minutely illuminated in the literature [28]. Circuit AGC for each cascade/stage must be designed in such a way that would be obtained the amplitude characteristic of cascade/stage, satisfying the requirements, presented into § of 1 and

2 present chapter. Output potential of the adjustable cascade/stage

$$U_{\text{BLX}} = I_{a_1} R_0. \quad (\text{II-107})$$

Since during the gain control of cascade/stage by a change in the bias voltage the plate load remains constant, the calculation of amplitude characteristic is reduced on the calculation of the dependence of the amplitude of the fundamental harmonic of the current of I_{a_1} (in the case of selective amplifiers and speech amplifiers) or it is simple the amplitude of anode current (in the case of the amplification of video pulses) from the amplitude of input signal.

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Equating the in turn right sides of the expressions (II.107) and (II.1), (II.3), (II.21), (II.47), (II.49), (II.51) and taking into account that the maximum factor of amplification of cascade/stage K_1 and the amplitude of the fundamental harmonic of the anode current of $I_{a_{1A}}$ of the work of cascade/stage in linear conditions are respectively equal to $K_1 = S F_0$ and $I_{a_{1A}} = S U_{\text{BLX}}$, is obtained, that the relation of the currents of $\frac{I_{a_1}}{I_{a_{1A}}} = f(x)$ depending on relative input voltage with the first method of obtaining LAX must change according to the law, described by expressions (II.4), (II.5) and (II.22), and with the second method - according to the law, described by expressions (II.48), (II.50) and (II.52).

Thus, curves, depicted on Fig. 13, also can be used during the

calculation of the logarithmic amplifier when the gain control of cascade/stages is conducted by changing the bias voltage.

§ 7. Use of an exponential dependence of current on the voltage of nonlinear cell/elements.

For obtaining LAX in single-stage amplifier in dynamic range to 35-40 dB, and also in multistage amplifier in sufficiently broad band with the method of the addition of output voltages can be used the different nonlinear cell/elements, which possess the exponential dependence between the current, which takes place through the cell/element, and the voltage, which are isolated on it. Such nonlinear cell/elements include different semiconductor devices and some types of vacuum lamps. From semiconductor devices for this purpose, approach cuprous oxide and germanium low-frequency rectifiers, silicon and germanium high-frequency diodes. Of vacuum lamps the sufficiently pronounced exponential dependence they have grid $i_c = f(U_c)$ and the anode-grid $i_a = f(U_c)$ of characteristic with small anode voltages. Let us examine the possible versions of obtaining LAX in amplifier.

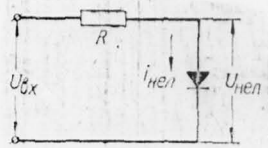


Fig. 47. Passive nonlinear logarithmizing chain/network.

Use of semiconductor devices.

As shown in work [32], the volt-ampere characteristic of semiconductor diode is described by the expression

$$i_{\text{нел}} = A [e^{\alpha (U_{\text{нел}} - i_{\text{нел}} r)} - 1], \quad (\text{II-108})$$

where A and α are constants; r - the volumetric resistor/resistance of semiconductor; $U_{\text{нел}}$ - the voltage, applied to diode.

Constant $\alpha = e/kT$, which comprises at room temperature of approximately 40 [in]^{-1} . Resistor/resistance r composes units (2-4) ohm, which makes it possible with sufficient low currents to disregard the product of $i_{\text{нел}} r$. In this case the expression (II.108) takes the form

$$i_{\text{нел}} = A (e^{\alpha U_{\text{нел}}} - 1), \quad (\text{II-109})$$

whence

$$U_{\text{нел}} = \frac{1}{\alpha} \ln \left(\frac{i_{\text{нел}}}{A} + 1 \right). \quad (\text{II-110})$$

If we consecutively with diode include/connect high resistor/resistance (Fig. 47), then it is possible to obtain current as independent alternating/variable, proportional to input voltage $U_{\text{вх}}$, i.e.

$$i_{\text{нел}} \approx \frac{U_{\text{вх}}}{R}.$$

In this case, between voltage on the diode of $U_{\text{нел}}$ and the input voltage of $U_{\text{вх}}$ dependence logarithmic

$$U_{nen} = \frac{1}{\alpha} \ln \left(\frac{U_{nx}}{AR} + 1 \right). \quad (II-111)$$

The dynamic resistance of germanium semiconductor diodes with zero smeshcheniii sufficiently greatly and for different types can have a value from units to dozens kilohm.

Thus, for instance, of diodes of the type of DG-Q this resistor/resistance reaches the value of 10-20 ccmas, of diodes of the type D9 2-10 ccmas. In order that expression (II.111) would be fulfilled with a sufficient degree of accuracy with the low currents of i_{nen} , resistor/resistance R must be undertaken the order of 50-100 ccmas.

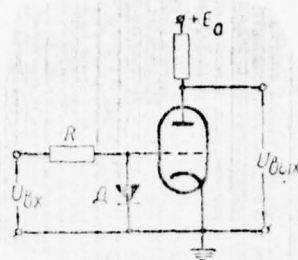


Fig. 48. Amplifier stage with the logarithmizing chain/network in grid circuit.

If we to the input of amplifier stage with factor of amplification K_1 , include/connect chain/network (Fig. 47), as this is shown in Fig. 48, then its amplitude characteristic will be described by the expression

$$U_{out} = \frac{K_1}{a} \ln \left(\frac{U_{in}}{AR} + 1 \right). \quad (II-112)$$

During the comparison of expressions (II.112) and (II.3) it is evident that in this case the coefficient

$$a = \frac{K_1}{a}.$$

Thus, by changing the factor of amplification of cascade/stage, it is possible to change coefficient of a .

Use of vacuum lamps.

Some types of vacuum lamps have the grid characteristics of $i_c = f(E_c)$, which sufficiently accurately they are approximated by exponential function within the large limits of a change in the stress on the control electrode (Fig. 49)

$$i_c = I_{c_0} e^{-\alpha E_c}, \quad (II-113)$$

where I_{c_0} - the value of grid current at grid voltage of $E_c = 0$; α is constant coefficient.

Figure 49 by prime shows the approximation of the grid characteristic of the tube of 6Ж1Н by the function of

$$i_c = 78 \cdot 10^{-6} e^{5E_c}$$

If we at the rated value of the voltage of aaaa conduct to grid the alternating voltage of signal, then the expression (II.113) of signs the following form:

$$i_c = I_{c0} e^{a(-E_c + U_c)}, \quad (II-114)$$

whence we find expression for the variable component of the grid voltage

$$U_c = \frac{1}{a} \ln \frac{i_c}{I_{c0}} + E_c.$$

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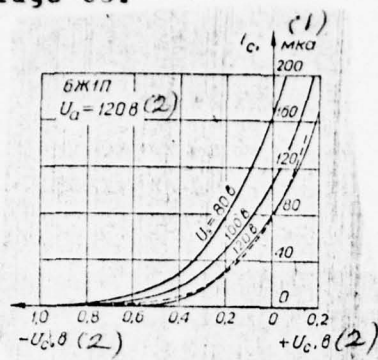


Fig. 49.

Fig. 49. The grid characteristics of the tube of the 6J1P:

$$i_c = 78 \cdot 10^{-4} e^{-5E_c}$$

Key: (1). μA . (2). in.

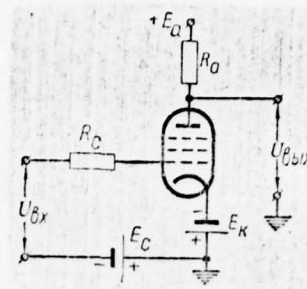


Fig. 50.

Fig. 50. Diagram of the logarithmizing cascade/stage with the use of a nonlinearity of grid characteristic.

For providing a proportionality between the input voltage of U_{bx} and the current of I_c into the grid circuit of tube, is necessary the sufficiently high resistor/resistance of R_c (Fig. 50). Then

$$I_c \cong \frac{U_{bx}}{R}$$

and

$$U_c = \frac{1}{a} \ln \frac{U_{bx}}{I_c R_c} + E_c.$$

For providing the greatest dynamic range of the LAX of cascade/stage the initial bias voltage of the E_c is selected by such, with which working gochka on the anode-grid characteristic of tube is located on linear section and its position corresponds to the beginning of grid characteristic. In this case, the tube works in linear conditions and output potential of the cascade/stage

$$\begin{aligned} U_{bix} &= U_c S R_H = \\ &= K_1 \left(\frac{1}{a} \ln \frac{U_{bx}}{I_c R_c} + E_c \right). \quad (II-115) \end{aligned}$$

The desired value of base of logarithm N , in terms of which must logarithmize the cascade/stage, in this case it is possible to select by change K_1 , i.e., by a change in the value of the resistor/resistance of R_a or grid-plate transconductance S . To change the slope/transconductance of pentode at the rated value of bias voltage possible, by changing stresses on screen grid.

Logarithmic amplitude characteristic in amplifier can be obtained, by utilizing pentodes with alternating/variable

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slope/transconductance, whose static anode-grid characteristics have sections of logarithmic character.

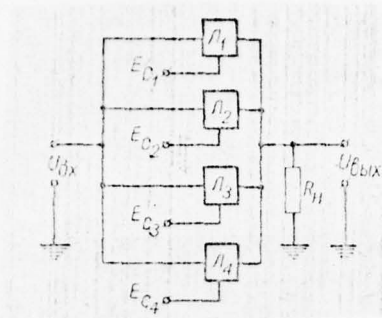


Fig. 51. The block diagram of the amplifier in which the LAX is obtained because of the logarithmic sections of grid-plate characteristics.

The logarithmic section of anode-grid characteristic can be obtained virtually in any pentode, after lowering anode voltage. For obtaining LAX in the amplifier several tubes they connect in parallel (Fig. 51). To the control electrodes of these tubes, is supplied the bias voltage of different level. Then each tube works between cutoff and saturation and its anode-grid characteristic is utilized on the determined part of the range of the LAX of amplifier. During the correct overlap of the characteristics of parallel tubes it is possible to obtain the sufficiently precise LAX of amplifier.

The amplifier, assembled by diagram in Fig. 51, possesses the following deficiency/lacks:

1) the amplifier gain is low and does not exceed the factor of amplification of one cascade/stage;

2) LKh amplifier it nchinetsya on the high level of input signal (on the order of 0.2-0.5 c). Therefore at the input of this logarithmic amplifier, it is necessary to place supplementary linear amplifier for the amplification of weak signals.

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Chapter Three

APERIODIC LOGARITHMIC AMPLIFIERS.

Aperiodic amplifier is called equipment/device, the factor of amplification of which does not depend on frequency over a wide range

of frequencies. For aperiodic amplifiers the ratio of the upper cut-off frequency of F_{max} to the lower cut-off frequency of F_{min} is comparatively great and considerably more than unit. In such amplifiers in the majority of cases, are contained the aperiodic circuits, which do not possess resonance properties, for example, effective resistance in conjunction with capacitance/capacities and π . Most frequently aperiodic are the low-frequency amplifiers.

Depending on the form of the amplified signals aperiodic amplifiers it is possible to divide into the amplifiers of harmonic signals, pulse signals (in abbreviated form pulse amplifiers) and of direct current.

The amplifiers of harmonic signals include the low-frequency amplifiers (UNC [- low-frequency amplifier]), intended for the amplification of the fluctuations of audio frequencies in the range from dozens hertz to 15-20 kHz.

Pulse are called the amplifiers, which amplify without noticeable distortion momentum/impulse/pulses or the rapidly being changed signals, frequency spectrum of which stretches from hundreds hertz to units megahertz. They include the video amplifiers, amplifying video pulses of current or voltage.

The amplifiers, which amplify very slow oscillations, including zero frequency, is conventionally designated as dc amplifiers (UPT).

even if they are intended for the voltage amplification or power.

The difference between the noted forms pronounces, for example, in approach to design and testing different aperiodic amplifiers from LAX. In connection with this it is most expedient to examine aperiodic amplifiers from LAX in connection with each of the types.

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§ 1. Logarithmic video amplifiers.

Logarithmic video amplifier with 1st type nonlinear divider/denominators.

Figure 52 depicts the schematic diagram of the video amplifier in which the LAX is obtained with the shunting of the plate loads of cascade/stages by 1st type nonlinear divider/denominators. The linear resistor/resistances of divider/denominators R_6 , R_{18} and R_{30} in diagram can no. Then the plate loads of cascade/stages are shunted only by nonlinear cell/elements - germanium semiconductor diodes of the type of D2J. With the same success can be used other types of diodes. During the amplification of video pulses the plate load of each cascade/stage must be shunted by two diodes, connected by different polarity. This is necessary in order to decrease the parasitic reverse/inverse overshoot which in logarithmic video amplifiers during an increase in the input signal reaches the

significant magnitude.

Figure 53 gives the experimental amplitude characteristics of one cascade/stage, assembled on the tube of 6J5P, with the anode resistor/resistance of the $R_a = 1,1$ of comas, shunted only by the diodes of the D2J of ($R_d = 0$) with the different cutoff voltages of $E_{sat_{D2J}}$ on them.

Supplementary resistor/resistance (resistor/resistances R_8 , R_9 , R_{20} , R_{21} , R_{32} and R_{33} in Fig. 52), from which is remove/taken the cut-off bias (see Fig. 33b), it is taken $R_{noc} = 100$ ohm.

Figure 54 depicts the experimental amplitude characteristics of cascade/stage with the anode resistor/resistance, shunted by 1st type nonlinear divider/denominator. Characteristics are given for two cases:

1) for the constant values of the resistor/resistances of the divider/denominator of the $R_d = 10$ of comas (resistor/resistance R_6 , R_{18} in Fig. 52) and of $R_{noc} = 100$ ohm and the different values of cutoff voltage (curves 1, 2 and 3);

2) for the constant values of the $R_d = 10$ of comas and $E_{sat_{D2J}} = 0,1$ ✓ ~~in~~ and for the different values of R_{noc} (curves 2, 4 and 5).

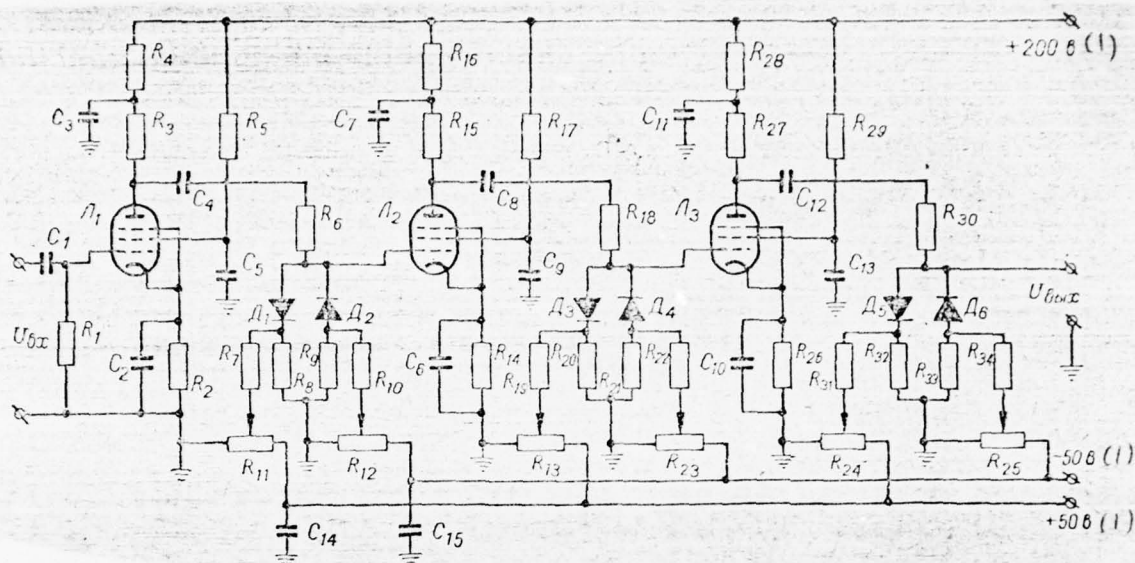


Fig. 52. Schematic diagram of logarithmic video amplifier with 1st type nonlinear divider/denominators: L_1, L_2, L_3 - 6J5P; $D_1, D_2, D_3, D_4, D_5, D_6$ - D2J; R_1 - 56 comas; R_2, R_{14}, R_{26} - 120 ohm; R_3, R_{15}, R_{27} - 1.1 comas; R_4, R_{16}, R_{28} - 5.1 comas; R_5, R_{17}, R_{29} - 33 comas; R_6, R_{18}, R_{30} - 500 ohm; $R_8, R_9, R_{20}, R_{21}, R_{22}, R_{33}$ - 100 ohm; $R_7, R_{10}, R_{19}, R_{22}, R_{31}, R_{34}$ - 15 comas; $R_{11}, R_{12}, R_{13}, R_{22}, R_{24}, R_{25}$ - 22 comas; C_1, C_4, C_8, C_{12} - 0.1 mkzh; $C_2, C_5, C_6, C_9, C_{10}, C_{13}, C_{14}, C_{15}$ - 10.0 mkzh; C_3, C_7, C_{11} - 2.0 mkzh.

Fig. 53. Amplitude characteristics of cascade/stage with the shunting of plate load only by nonlinear cell/elements: 1 - $E_{\text{аннел}} = 0,5$ ~~in~~; 2 - $E_{\text{аннел}} = 0,15$ ~~in~~; 3 - $E_{\text{аннел}} = 0,1$ ~~in~~; 4 - $E_{\text{аннел}} = 0,05$ ~~in~~; 5 - $E_{\text{аннел}} = 0$.
Key: (1). ~~in~~. (2). ohm.

Fig. 54. Amplitude characteristics of cascade/stage with the shunting of plate load by 1st type nonlinear divider/denominator: $R_{\text{дог}} = 100$ ohm; $E_{\text{аннел}} = 0,1$ ~~in~~; 1 - $E_{\text{аннел}} = 0,2$ ~~in~~; 2 - $E_{\text{аннел}} = 0,1$ ~~in~~; 3 - $E_{\text{аннел}} = 0,05$ ~~in~~; 4 - the $R_{\text{дог}} = 0,5$ ~~of comas~~ ~~12 ohm~~; 5 - the $R_{\text{дог}} = 2$ ~~of comas~~ ~~12 ohm~~.
Key: (1). ~~in~~. (2). ~~comas~~.

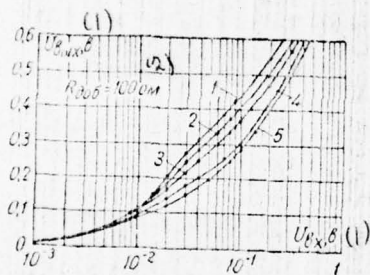


Fig. 53.

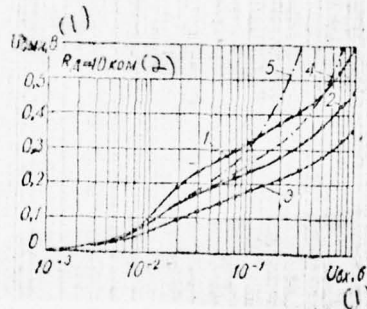


Fig. 54.

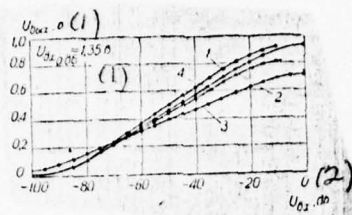


Fig. 55. Amplitude characteristics of three-stage logarithmic video amplifier with 1st type nonlinear divider/denominators: 1 - $R_d = 1,1$

$k \text{ ohm}$ $R_d = 0$; $E_{\text{зап.нел.}} = 0,1 \text{ V}$; 2 - $R_d = 1,1$ $k \text{ ohm}$
 $R_d = 0$; $E_{\text{зап.нел.}} = 0,06 \text{ V}$; 3 - $R_d = 2$ $k \text{ ohm}$; $R_d = 0,5$ $k \text{ ohm}$; $E_{\text{зап.нел.}} = 0$;
 4 - $R_d = 1,1$ $k \text{ ohm}$; $R_d = 0,5$ $k \text{ ohm}$; $E_{\text{зап.нел.}} = 0,08 \text{ V}$;
 $E_{\text{зап.нел.}} = 0,07 \text{ V}$.

Figure 54 shows that upon the incorporation of the resistor/resistance of R_{π} expands itself the dynamic range the LAX of cascade/stage, but in this case it decreases the differential factor of amplification of cascade/stage of work in the quasi-linear mode/conditions which for providing a successive work of cascade/stages in the most general case must be equal to unit. For satisfaction of this condition with an increase in the resistor/resistance of R_A , it is necessary to increase the resistor/resistance of $R_{доб}$. By a change in the value of the resistor/resistance of $R_{доб}$ it is possible to obtain the necessary amplitude characteristic of cascade/stage. On the basis of Figs. 53 and 54 it is possible to make the following conclusions.

In one cascade/stage of the amplification of video pulses with the plate load, shunted only by a diode of the type of D2J, it is possible to obtain LAX in the range 18-20 dB. The greatest range LAX is obtained with cutoff voltage on the diode of $E_{зап_{нел}} = 0,05 \div 0,1$ V in the supplementary resistor/resistance of $R_{доб} = 100 \div 200$ ohm.

Range LAX in one cascade/stage with the plate load, shunted by 1st type nonlinear divider/denominator, can be obtained to 25-28 dB. In the case of application/use as the nonlinear cell/elements of diodes of the type D2, the greatest range LAX is obtained with the resistor/resistances of the $R_A = 10 \div 12$ k ohm, $R_{доб} = 100 \div 200$ ohm and the voltage of $E_{зап_{нел}} = 0,1 \div 0,2$ V.

For obtaining the amplitude characteristic of cascade/stage, necessary in the successive work of nonlinear cascade/stages in n-cascade amplifier, the resistor/resistance of $R_{доб}$ one should increase to 0.5-1 times that it leads to a decrease in the range of the LAX of cascade/stage to 18-20 dB.

Thus, in amplifier aperiodic cascade/stage with the plate load, shunted by 1st type nonlinear divider/denominator with diodes of the type D2, during satisfaction of the successive working condition of nonlinear cascade/stages range LAX can be obtained to 20-25 dB. This will make it possible in three-stage amplifier to obtain LAX with relative accuracy 2-3% in the range to 60-70 dB.

Figure 55 depicts the experimental amplitude characteristics of the three-stage logarithmic video amplifier, schematic diagram of which is shown in Fig. 52, for the different values of R_a , R_d and $E_{зап. нел.}$. Zero reference level is accepted $U_{вх, доб} = 1,35$ V. Figure 55 shows that without the resistor/resistance of R_d the dynamic range the LAX of amplifier is somewhat less than 60 dB (curves 1 and 2), but with it - are somewhat more than 60 dB (curves 3 and 4). Relative accuracy LAX in the indicated range $\delta = 2\%$.

Relative accuracy LAX both in aperiodic and in selective amplifiers was measured as follows. The experimental characteristic of amplifier was removed/taken by several operators (it is not less than three) on several times (it is not less than 5 times). Metering equipment was applied with class of accuracy 2-3%. The experimental

points, taken by all operators, were deposited to one sheet of paper by size 500 Oct. 1000 mm with semilogarithmic scale. Then was carried out straight line so that the greatest number of experimental points is close near it. In this case, the absolute and relative deflections of the greatest number of experimental points from straight line were accepted respectively as absolute and relative deflections δ real by LAX from accurately logarithmic.

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Random single deviations of experimental points, which are not confirmed by several operators, during the determination of relative accuracy real by the LAX of amplifier in the assigned dynamic range of iskluychayis'.

For obtaining high relative accuracy 1-20/c real by the LAX of amplifier in wide dynamic range it is necessary thoroughly to take/select on the uniformity of the parameters both amplifier tubes and the semiconductor diodes. Amplifier tubes one should take/select on slope/transconductance and anode current with spread not more than 5c/o.

The sufficiently good results in the relation to the accuracy of the LAX of amplifier are obtained during the selection of semiconductor diodes on the measurement of current the minimum at three values of direct/constant voltage on it. For example for diodes of

the type of DG-Q and D2 one should measure the current with the following voltages on the diode: $+0.1$; $+1$; -5 V. For the diodes of the type D9, of D101 - D102 - with $+ (0.1-0.2)$; $+ (0.3-0.6)$; -5 V.

The upper limits of stress must be applied in the selection of diodes with the lesser slope/transconductance of the volt-ampere characteristic, but lower - in the selection of diodes with larger slope/transconductance. The scatter of the values of the currents of separate diodes must not exceed 3-5%/c.

For producing the cutoff voltages of $E_{\text{зан}} E_{\text{н}} E_{\text{н}}$ diagram, are applied two stabilized source of two polarity $+50$ and -50 V. For obtaining by sufficiently precise with IAX the cutoff voltage of $E_{\text{зан}} E_{\text{н}} E_{\text{н}}$ on each diode is supplied from separate potentiometer (R_{11} , R_{12} etc., Fig. 52). When is not required high accuracy the IAX of amplifier, voltage of $E_{\text{зан}} E_{\text{н}} E_{\text{н}}$ it is possible to remove/take only from two potentiometers to which are given respectively positive and negative voltages.

By applying as nonlinear cell/elements germanium diodes of the type of DG-S and DG-P, it is possible to obtain IAX in one cascade/stage to 40-50 dB. Fig. 56 shows the experimental amplitude characteristics of one cascade/stage, assembled on the tube of 6J5P with the plate load of the $R_1 = 1.1 \text{ k}\Omega$ shunted by the diodes of DG-P4 (is curve 1) and of DG-S2 (is curve 2). Range IAX in the first case reaches by 51 dB, in the second - 54 dB.

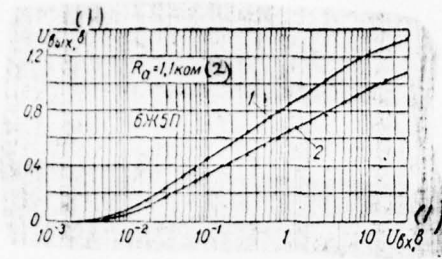


Fig. 56. Amplitude characteristics of cascade/stage with the plate load, shunted by semiconductor diodes of the type of DG-P4 (1) and of DG-S2 (2).

Key: (1). *V* (2). *Rohm*

It is necessary to note that with an increase in the input signal on 50-60 dB relative to the level on which begins the LAX, at the output/yield of n-cascade video amplifier, it appears considerable parasitic reverse/inverse overshoot after the break-down of the momentum/impulse/pulse of signal.

This phenomenon is caused by the fact that with an increase of signal the resistor/resistance of nonlinear cell/elements decreases, and the time constants of the circuits of the charge of transient capacitance/capacities, in consequence of which transient capacitance/capacities, especially in the last/latter and penultimate cascade/stages, for the pulse action time, they charge themselves up to great significance of voltages. During the discharge of these capacitance/capacities after the break-down of momentum/impulse/pulse, appear large parasitic reverse/inverse overshoots, as a result of which in amplifier for a prolonged time is lost sensitivity. Large parasitic overshoots in video amplifiers from LAX - these are the fundamental reason, which limits obtaining the large range of LAX by means of the shunting of the plate loads of cascade/stages by nonlinear cell/elements.

For the elimination of this phenomenon the nonlinear cell/elements, which shunt the plate load of cascade/stage, one should include to transient capacitance/capacity. The schematic diagram of this nonlinear cascade/stage is depicted on Fig. 57. In this diagram nonlinear cell/elements earth referenced are blocked by capacitance/capacities C_6 and C_5 , since they are found under high

restoring potential. The cutoff voltages of $E_{\text{антен}}$ on nonlinear cell/elements are supplied from voltage dividers R_7 , R_8 , R_9 and R_{12} , R_{13} , R_{14} which are connected directly to of anode power supply. In this case is not required the source of negative voltage. For convenience in the selection of the voltages of the $E_{\text{антен}}$ of resistor/resistance R_8 and R_{13} , are taken by variables.

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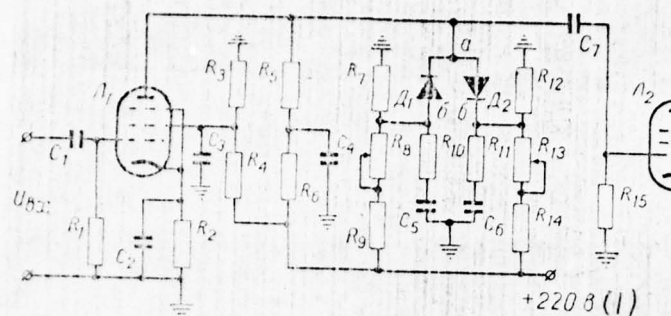


Fig. 57. Schematic diagram of cascade/stage upon the switching on not of linear cell/elements to the transient capacitance/capacity: L_1 - 6J5P; D_1, D_2 - D2J; R_1, R_{15} - 100 $K\Omega$; R_2 - 200 Ω ; R_3 - 15 $K\Omega$; R_4 - 6.8 $K\Omega$; R_5 - 11 $K\Omega$; R_6 - 6.2 $K\Omega$; R_7, R_{12} - 470 Ω ; R_8, R_{13} - 22 $K\Omega$; R_{10}, R_{11} - 100 Ω ; R_9, R_{14} - 200 $K\Omega$; C_1, C_7 - 0.1 μF ; C_2, C_3, C_4, C_5, C_6 - 10 μF .
Key: (1). ✓

The voltage of $E_{\text{зап.нел}}$ on each of the diodes is equal to a potential difference at points a and b. Resistor/resistances R_{10} and R_{11} are included for obtaining the necessary amplitude characteristic of cascade/stage.

The voltage of anode power supply must be high-stability, since its instability produces change in the stress of $E_{\text{зап.нел}}$, that in turn, it leads to distortion common/general/total by the LAX of multistage amplifier. Thus, for instance, for providing a stability of the stress of the $E_{\text{зап.нел}}$ of order 5-10o/c stability of the voltage of anode power supply must be order 0.02-0.05o/c. This is one of the deficiency/lacks in the diagram upon the switching on of nonlinear cell/elements to transient capacitance/capacity. The second deficiency/lack in this diagram is the dependence of the stress level of $E_{\text{зап.нел}}$ from the parameters of the amplifier tube which change in the course of time with the ageing of tube.

In order that voltage on the screen grid of tube would not depend on the porosity of the amplified momentum/impulse/pulses, the latter is supplied from the divider/denominator, which consists of resistor/resistances R_4 and R_3 . In the diagram, depicted on Fig. 57, also can be used 1st type nonlinear divider/denominator. On its parameters this diagram is equivalent to the diagram, depicted on Fig. 52.

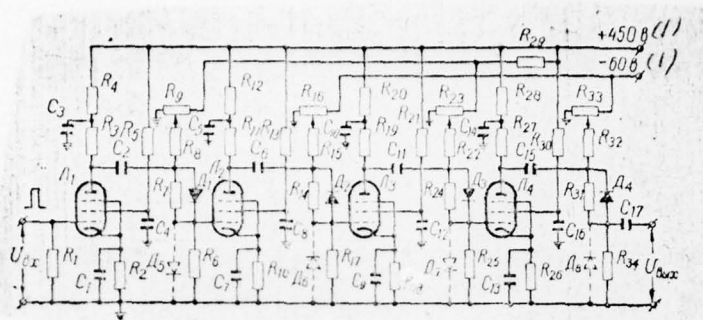


Fig. 58. Schematic diagram of logarithmic video amplifier with 2nd type nonlinear divider/denominators: L_1, L_2, L_3, L_4 - 6J1P; D_1, D_2, D_3, D_4 - D2J; D_5, D_6, D_7, D_8 - DG-Q8 $R_3, R_{11}, R_{19}, R_{27}$ - 30 Kohm $R_4, R_{12}, R_{20}, R_{28}$ - 3 Kohm $R_7, R_{14}, R_{24}, R_{31}$ - 300 Kohm $R_9, R_{16}, R_{23}, R_{33}$ - 33 Kohm; $R_5, R_{13}, R_{21}, R_{30}$ - 120 Kohm $R_1, R_6, R_8, R_{15}, R_{17}, R_{22}, R_{25}, R_{32}$ - 180 Kohm R_2, R_{18} - 160 ohm; R_{10}, R_{26} - 210 ohm; R_{29} - 91 Kohm C_1, C_7, C_9, C_{15} - 25.0 μF ; $C_3, C_4, C_5, C_8, C_{10}, C_{12}, C_{14}, C_{16}$ - 20 μF ; $C_2, C_6, C_{11}, C_{15}, C_{17}$ - 0.1 μF .

Key: (1). ✓

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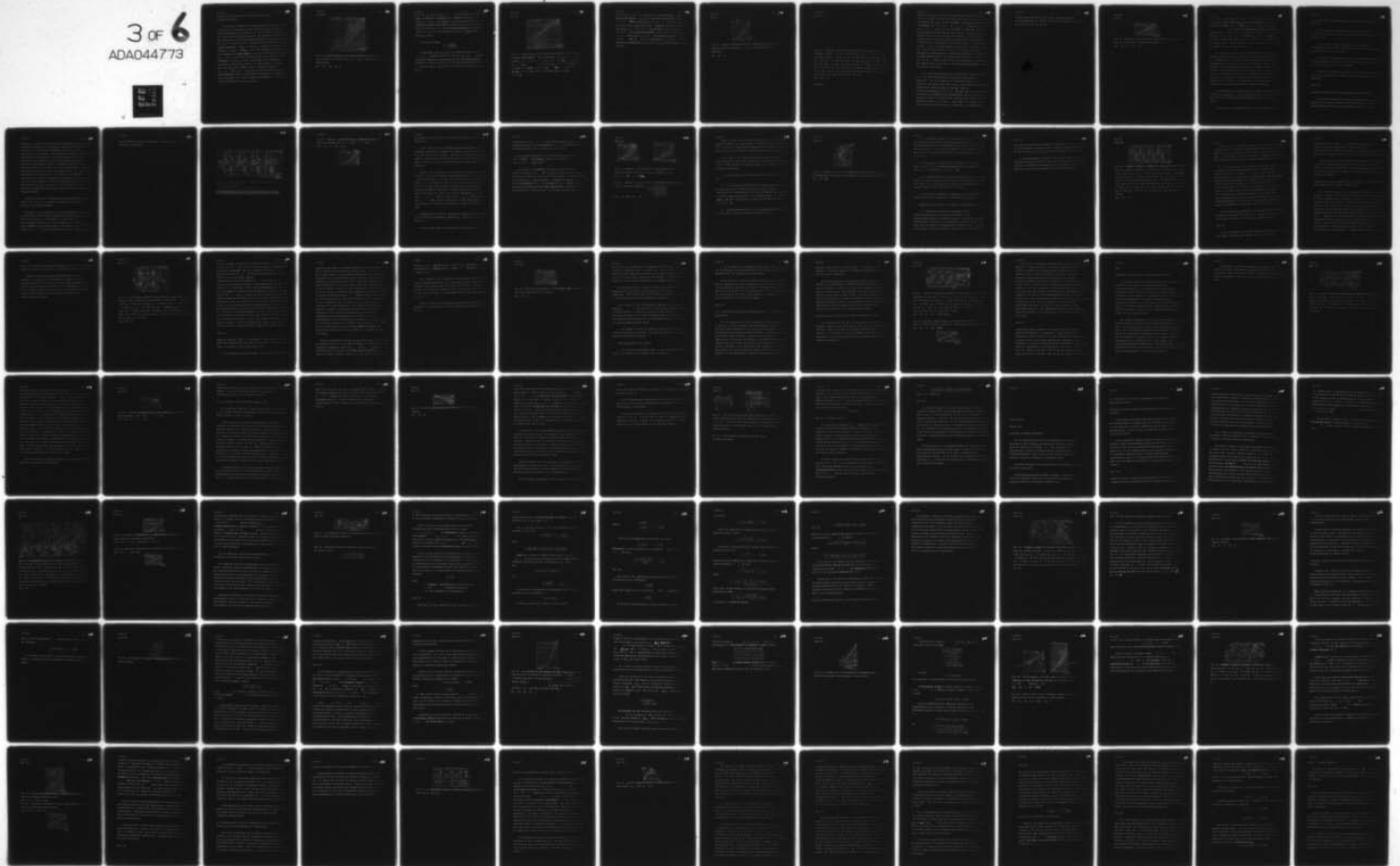
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Logarithmic video amplifier with 2nd type nonlinear divider/denominators.

The schematic diagram of the video amplifier in which the LAX is obtained with the shunting of plate loads by 2nd type nonlinear divider/denominators, is given in Fig. 58. Amplifier logarithmizes the video pulses of positive polarity. As nonlinear cell/elements in this diagram, are applied germanium semiconductor diodes (D_1 , D_2 , D_3 and D_4) of the type the "D2J", which have high resistor/resistance in opposite direction. Figure 59 shows the calculated and experimental curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ changes in the entry impedance of the diode of D2J, connected by diagram ~~Fig. 35~~ ^{Fig.} 35, with the different bias voltages of $E_{\text{смнел}}$ on it. Curves are designed for the video pulses of voltage according to formula (II.101), experimental check is produced according to substitution method. By nature curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ (Fig. 59) they differ somewhat from the required curves of $R_{\text{нел}} = f(z_{\text{нел}})$ (Fig. 26). In the zone of the high stresses of $U_{\text{нелс}}$ this difference easily is removed upon switching on in parallel to diode sufficient high linear resistor/resistance of R_n (in Fig. 58 resistor/resistance R_7 , R_{14} , R_{24} , R_{31}).

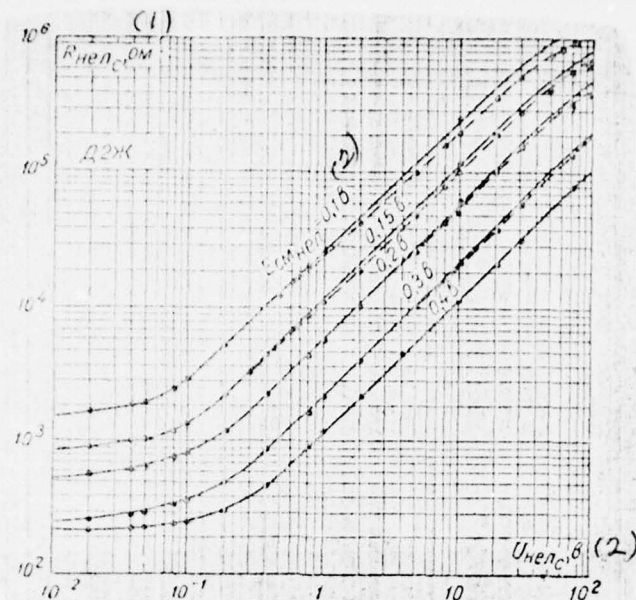


Fig. 59. Curved changes in the resistor/resistance of the diode of D2J, connected in diagram in Fig. 35: — calculated; experimental.

Key: (1). ohm. (2) V.

In the zone of small stresses of $U_{\text{нелс}}$ the difference between the curves in question is insignificant. Figure 60 depicts the real curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ of a change in the resistor/resistance of the equivalent nonlinear cell/element, which consists of in parallel connected the diode of D2J and resistor/resistances of $R_{\text{н}} = 3 \cdot 10^5$ and $1.3 \cdot 10^5$ ohm, with the bias voltages of $E_{\text{смнелс}} = 0.1$ and 0.15 V (unbroken curves).

Resistor/resistance

$$R_{\text{нелс}} = \frac{R_{\text{нелс}} R_{\text{н}}}{R_{\text{нелс}} + R_{\text{н}}}.$$

In this same figure by primes are shown the required curved $R_{\text{нелс}} = f(U_{\text{нелс}})$, calculated from the curves of $R_{\text{нелс}} = f(x_{\text{нелс}})$, for the last/latter nonlinear cascade/stage of the five-stage amplifier, assembled on tubes of the type of 6J1P (slope/transconductance of tube $S = 5.2$ mA/V; curves 3 and 4) and of 6J20P ($S = 17$ mA/V; curves 5, 6 and 7).

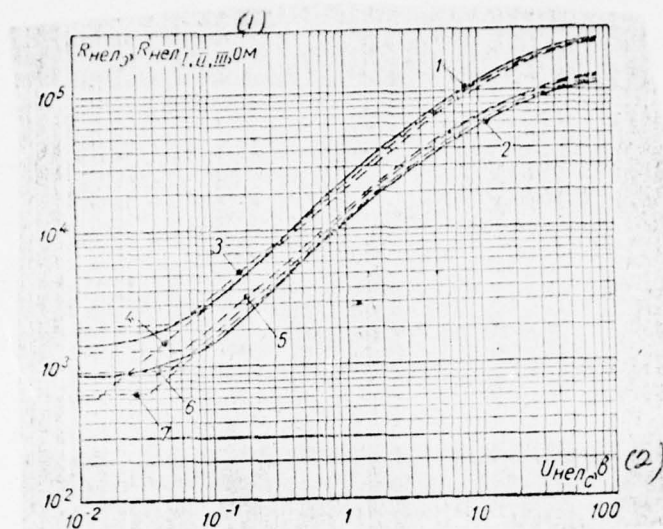


Fig. 60. Curved changes in the resistor/resistance of the equivalent nonlinear cell/element: — are real $R_{нел, \beta} = \varphi(U_{нел, \beta})$; ---- the

required $R_{нел I, II, III} = f(U_{нел, \beta})$; 1 - $E_{см, нел} = 0,1$ V; $R_n = 300$ k Ω ; 2 - $E_{см, нел} = 0,15$ V; $R_n = 130$ k Ω ; 3 - $R = 2,2$ k Ω ; 4 - $R = 2,1$ k Ω ; ($S = 5,2$ mA/V; $R_a = 30$ k Ω ; $U_{вых1} = 0,05$ V); 5 - $R = 640$ ohm; 6 - $R = 630$ ohm; 7 - $R = 620$ ohm; ($S = 17,5$ mA/V; the $R_a = 15$ k Ω ; $U_{вых1} = 0,03$ V).

For the tube of 6J1P, the calculation is produced with $R_d = 2,2 \cdot 10^3$ and $2,1 \cdot 10^3$ ohm and $U_{вых1} = 0,05$ V ; for the tube of 6J20P - with $R_d = 640, 630$ ^{and} ~~even~~ 620 ohm and $U_{вых1} = 0,03$ V . Figure 60 shows that the experimental curved $R_{нелг} = \varphi(U_{нелг})$ coincide sufficiently well with the dependences of $R_{нел} = f(U_{нелг})$ for the tube of the 6J1P with of $R_d = 2,2 \cdot 10^3$ ohm (resistor/resistances R_6, R_{17} etc. in Fig. 58), an $R_n = 3 \cdot 10^5$ ohm and an $F_{смнел} = 0,1$ V ; for the tube of 6J20P - with $R_d = 630$ ohm, an $R_n = 1,3 \cdot 10^5$ ohm and an $E_{смнел} = 0,15$ V. This it indicates the possibility of obtaining precise by LAX in much cascade amplifier.

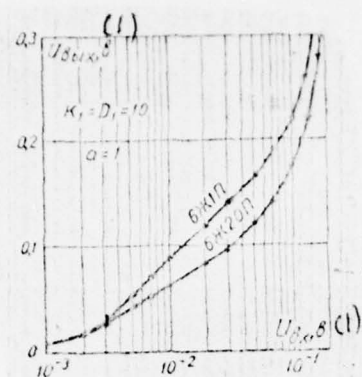


Fig. 61. Amplitude characteristics of cascade/stage with 2nd type nonlinear divider/denominator: — the calculation; experiment.

Key: (1). ✓

Fig. 63. Schematic diagram of logarithmic video amplifier with the nonlinear feedback: L_1, L_2, L_3, L_4 6J5E; $D_1, D_2, \dots, D_7, D_8$ - D2J; $D_9, D_{10}, D_{11}, D_{12}$ - DG-Q8; R_1, R_9, R_{17}, R_{25} 100 $k\Omega$; $R_2, R_{10}, R_{18}, R_{26}$ - 100 $k\Omega$; $R_7, R_8, R_{15}, R_{16}, R_{23}, R_{24}, R_{31}, R_{32}$ - 22 $k\Omega$; $R_6, R_{14}, R_{22}, R_{30}$ - 56 $k\Omega$; $R_3, R_{11}, R_{19}, R_{27}$ - 4.7 $k\Omega$; $R_4, R_{12}, R_{20}, R_{28}$ - 4.3 $k\Omega$; $R_5, R_{13}, R_{21}, R_{29}$ - 6.2 $k\Omega$; $C_1, C_6, C_{11}, C_{16}, C_{21}$ are 0.1 μF ; C_2, C_7, C_{12}, C_{17} is 0.01 μF ; C_3, C_8, C_{13}, C_{18} - 30.0 μF ; $C_4, C_5, C_9, C_{10}, C_{14}, C_{15}, C_{19}, C_{20}$ - 2.0 μF .

Key: (1) - V .

Figure 61 depicts as solid lines calculated from formulas (I.2), (I.11) and (I.23) the amplitude characteristics of the cascade/stages, assembled on the tubes of 6J1P and 6J20P. During the calculation it is accepted: $K_1 = D_1 = 10$; $a = 1$; $U_{ax1} = 0,005$ V for the tube of 6J1P and $U_{ax1} = 0,003$ V for the tube of 6J20P. In this same figure are plotted/applied the experimental data (point). From the analysis of characteristics, it is evident, then experimental characteristic somewhat differs from the required characteristic to larger side in the beginning of logarithmic section and in lesser - on quasi-linear section. In the n-cascade amplifier of deviation, they must average out. This one can see well from Fig. 62, in which are given the experimental characteristics of four-stage amplifiers; the assembled on tubes 6J1P and 6J20P. The initial reference level is accepted $U_{ax0.5} = 0,1$ V. Dynamic range LAX for both amplifiers is equal to 80 dB. Accuracy LAX in all range in the thoroughly fixed amplifier can be obtained order 2-3o/o.

one of the deficiency/lacks in the amplifier, depicted on Fig. 58, is the sharp amplification of parasitic reverse/inverse overshoots. For the elimination of this deficiency/lack in the circuit of the control electrodes of tube, are connected supplementary semiconductor diodes (D_5 , D_6 , D_7 and D_8). Then the resistor/resistances of R_{11} (R_9 , R_{17} , R_{25} and R_{33}) must be designed taking into account the effect of the supplementary diodes, the degree of shunting of which is different with different bias voltages on the fundamental diodes (D_1 , D_2 etc.). Bias voltage on supplementary diodes depends on bias voltage on fundamental. As supplementary

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diodes utilize the diodes, which have comparatively small resistor/resistance in forward direction, for example, the diodes of the type of DG-Q8, D9A and D9B.

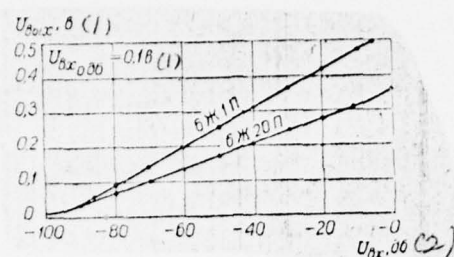


Fig. 62. Amplitude characteristics of logarithmic video amplifier with 2nd type nonlinear divider/denominators.

Key: (1). \checkmark (2). dB.

In the diagram, depicted on Fig. 58, are applied the diodes of the type of DG-Q8. Bias voltages on the fundamental diodes are respectively equal: $E_{\text{см.нел.1}} = +0,1 \text{ V}$; $E_{\text{см.нел.2}} = E_{\text{см.нел.3}} = -0,11 \text{ V}$; $E_{\text{см.нел.4}} = +0,09 \text{ V}$;

bias voltage on supplementary diodes are equal to $0.04-0.05 \text{ V}$. In this case, the resistor/resistances of R_x have the following values: $R_6 = R_{25} = 8.2 \text{ K ohm}$ $R_{17} = R_{34} = 7.5 \text{ K ohm}$. By including supplementary diodes, during a change in the input voltage in dynamic range 80 dB the parasitic relative overshoot on the output of amplifier can be decreased to 50%.

The diagram in question has the following essential advantage. Since in anode circuit in parallel to the anode resistor/resistance of R_a is included the nonlinear cell/element whose resistor/resistance grow/rises with an increase by it of the voltage of signal, during sufficiently high anode resistor/resistance common/general/total load impedance of cascade/stage also will increase with an increase in the signal. By taking into account this phenomenon, in the diagram in question it is possible to obtain the more stable delay time of the signal, than in diagram in the shunting of the plate loads of cascade/stages by 1st type nonlinear divider/denominators.

A deficiency/lack in the amplifier is somewhat an increased noise voltage on output/yield. This is explained by the fact that signal it passes through the semiconductor diodes which create considerable noises.

Carried out by the author theoretical and experimental studies

[5] showed that, by applying 1st type nonlinear divider/denominator, possible:

in one nonlinear cascade/stage to obtain dynamic range LAX to 35-40 dB, in this case the LAX of cascade/stage it begins with input voltage 3-8 mV;

To carry out a strictly successive work of nonlinear cascade/stages and to obtain accuracy the LAX of n-cascade amplifier in the range to 100-120 dB 2-30/o;

To carry out a virtually instantaneous restoration/reduction of the sensitivity of amplifier after the break-down of large signals in all dynamic range of the LAX of amplifier;

to obtain in logarithmic amplifier the sufficiently stable delay time in the signal during a change in it in all range of the LAX of amplifier.

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Logarithmic video amplifier with nonlinear current feedback.

The schematic diagram of four-stage logarithmic video amplifier with nonlinear current feedback is depicted on Fig. 63. Video amplifier logarithmizes the momentum/impulse/pulses of negative

polarity. In order that amplifier would logarithmize the video pulses of positive polarity, it is necessary to change the polarity of the switching on of nonlinear cell/elements and take on them the corresponding bias voltages. Let us agree the amplifier, intended for the logarithmic operation of the momentum/impulse/pulses of one polarity, to call asymmetric. As the nonlinear cell/elements, connected in the cathode circuits of cascade/stages, are taken germanium diodes of the type of D2J. For a decrease in the initial resistor/resistance of nonlinear cell/element, the R_{non} during the amplification of weak signals in the cathode circuit of each cascade/stage is included in parallel on two diodes (D_1 and D_2 , D_3 and D_4 , etc.). Bias voltages to nonlinear cell/elements are supplied from potentiometers R_8 , R_{16} , R_{24} and R_{32} . For the creation of bias voltages, are required two stabilized supply of power of positive and negative polarity.

Detailed calculation of logarithmic video amplifier is given in chapter VII. Here it is expedient to examine the selection of nonlinear cell/elements (diodes).

Recurrence of the parameters of the cell/elements of polychaetya by sufficiently good during the measurement of the current, which takes place through the cell/element, at three values of direct/constant voltage. one of the measurements of current one should produce by the voltage, equal to the computed value of the bias voltage of E_{bias} two other measurements they are conducted by the

same voltages, as during the selection of diodes in the case of the shunting of plate load.

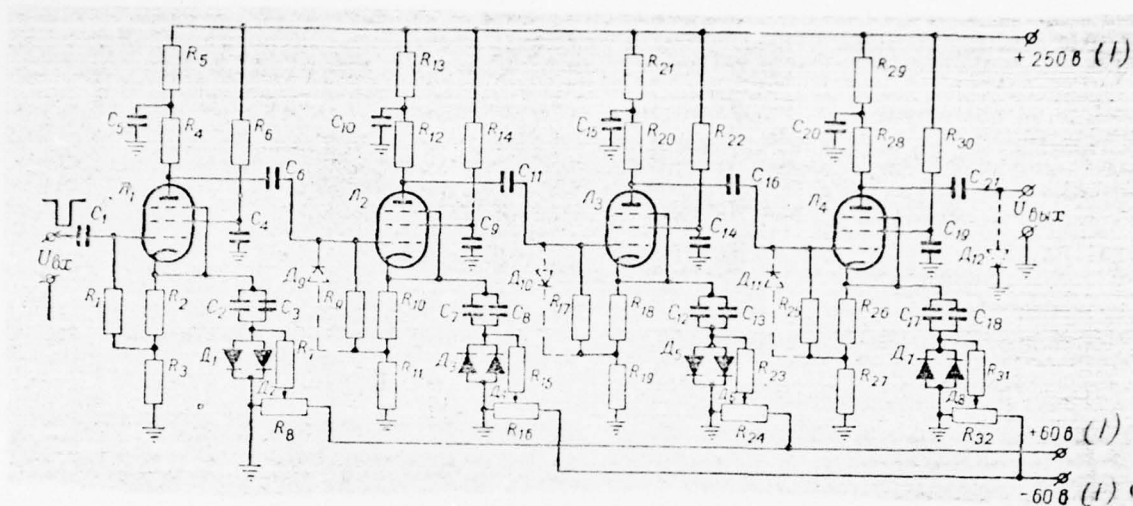


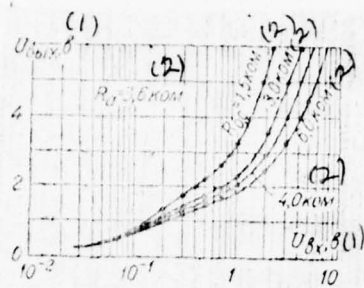
Fig. 63. Schematic diagram of logarithmic video amplifier with nonlinear feedback:

л = tube; д = diode; ком = kohm; мкф = μF .

$\text{Л}_1, \text{Л}_2, \text{Л}_3, \text{Л}_4$ — 6Ж5П; $\text{Д}_1, \text{Д}_2, \dots, \text{Д}_7, \text{Д}_8$ — Д2Ж; $\text{Д}_9, \text{Д}_{10}, \text{Д}_{11}, \text{Д}_{12}$ — ДГ-118; $\text{R}_1, \text{R}_2, \text{R}_3, \text{R}_4, \text{R}_5, \text{R}_6, \text{R}_7, \text{R}_8, \text{R}_9, \text{R}_{10}, \text{R}_{11}, \text{R}_{12}, \text{R}_{13}, \text{R}_{14}, \text{R}_{15}, \text{R}_{16}, \text{R}_{17}, \text{R}_{18}, \text{R}_{19}, \text{R}_{20}, \text{R}_{21}, \text{R}_{22}, \text{R}_{23}, \text{R}_{24}, \text{R}_{25}, \text{R}_{26}, \text{R}_{27}, \text{R}_{28}, \text{R}_{29}, \text{R}_{30}, \text{R}_{31}, \text{R}_{32}$ — 100 ком; $\text{R}_1, \text{R}_{10}, \text{R}_{11}, \text{R}_{12}, \text{R}_{13}, \text{R}_{14}, \text{R}_{15}, \text{R}_{16}, \text{R}_{17}, \text{R}_{18}, \text{R}_{19}, \text{R}_{20}, \text{R}_{21}, \text{R}_{22}, \text{R}_{23}, \text{R}_{24}, \text{R}_{25}, \text{R}_{26}, \text{R}_{27}, \text{R}_{28}, \text{R}_{29}, \text{R}_{30}, \text{R}_{31}, \text{R}_{32}$ — 22 ком; $\text{R}_1, \text{R}_{10}, \text{R}_{11}, \text{R}_{12}, \text{R}_{13}, \text{R}_{14}, \text{R}_{15}, \text{R}_{16}, \text{R}_{17}, \text{R}_{18}, \text{R}_{19}, \text{R}_{20}, \text{R}_{21}, \text{R}_{22}, \text{R}_{23}, \text{R}_{24}, \text{R}_{25}, \text{R}_{26}, \text{R}_{27}, \text{R}_{28}, \text{R}_{29}, \text{R}_{30}, \text{R}_{31}, \text{R}_{32}$ — 56 ком; $\text{R}_1, \text{R}_{10}, \text{R}_{11}, \text{R}_{12}, \text{R}_{13}, \text{R}_{14}, \text{R}_{15}, \text{R}_{16}, \text{R}_{17}, \text{R}_{18}, \text{R}_{19}, \text{R}_{20}, \text{R}_{21}, \text{R}_{22}, \text{R}_{23}, \text{R}_{24}, \text{R}_{25}, \text{R}_{26}, \text{R}_{27}, \text{R}_{28}, \text{R}_{29}, \text{R}_{30}, \text{R}_{31}, \text{R}_{32}$ — 4,3 ком; $\text{R}_1, \text{R}_{10}, \text{R}_{11}, \text{R}_{12}, \text{R}_{13}, \text{R}_{14}, \text{R}_{15}, \text{R}_{16}, \text{R}_{17}, \text{R}_{18}, \text{R}_{19}, \text{R}_{20}, \text{R}_{21}, \text{R}_{22}, \text{R}_{23}, \text{R}_{24}, \text{R}_{25}, \text{R}_{26}, \text{R}_{27}, \text{R}_{28}, \text{R}_{29}, \text{R}_{30}, \text{R}_{31}, \text{R}_{32}$ — 6,2 ком; $\text{C}_1, \text{C}_2, \text{C}_3, \text{C}_4, \text{C}_5, \text{C}_6, \text{C}_7, \text{C}_8, \text{C}_9, \text{C}_{10}, \text{C}_{11}, \text{C}_{12}, \text{C}_{13}, \text{C}_{14}, \text{C}_{15}, \text{C}_{16}, \text{C}_{17}, \text{C}_{18}, \text{C}_{19}, \text{C}_{20}, \text{C}_{21}, \text{C}_{22}, \text{C}_{23}, \text{C}_{24}, \text{C}_{25}, \text{C}_{26}, \text{C}_{27}, \text{C}_{28}, \text{C}_{29}, \text{C}_{30}, \text{C}_{31}, \text{C}_{32}$ — 0,1 мкф; $\text{C}_1, \text{C}_2, \text{C}_3, \text{C}_4, \text{C}_5, \text{C}_6, \text{C}_7, \text{C}_8, \text{C}_9, \text{C}_{10}, \text{C}_{11}, \text{C}_{12}, \text{C}_{13}, \text{C}_{14}, \text{C}_{15}, \text{C}_{16}, \text{C}_{17}, \text{C}_{18}, \text{C}_{19}, \text{C}_{20}, \text{C}_{21}, \text{C}_{22}, \text{C}_{23}, \text{C}_{24}, \text{C}_{25}, \text{C}_{26}, \text{C}_{27}, \text{C}_{28}, \text{C}_{29}, \text{C}_{30}, \text{C}_{31}, \text{C}_{32}$ — 0,01 мкф; $\text{C}_1, \text{C}_2, \text{C}_3, \text{C}_4, \text{C}_5, \text{C}_6, \text{C}_7, \text{C}_8, \text{C}_9, \text{C}_{10}, \text{C}_{11}, \text{C}_{12}, \text{C}_{13}, \text{C}_{14}, \text{C}_{15}, \text{C}_{16}, \text{C}_{17}, \text{C}_{18}, \text{C}_{19}, \text{C}_{20}, \text{C}_{21}, \text{C}_{22}, \text{C}_{23}, \text{C}_{24}, \text{C}_{25}, \text{C}_{26}, \text{C}_{27}, \text{C}_{28}, \text{C}_{29}, \text{C}_{30}, \text{C}_{31}, \text{C}_{32}$ — 30,0 мкф; $\text{C}_1, \text{C}_2, \text{C}_3, \text{C}_4, \text{C}_5, \text{C}_6, \text{C}_7, \text{C}_8, \text{C}_9, \text{C}_{10}, \text{C}_{11}, \text{C}_{12}, \text{C}_{13}, \text{C}_{14}, \text{C}_{15}, \text{C}_{16}, \text{C}_{17}, \text{C}_{18}, \text{C}_{19}, \text{C}_{20}, \text{C}_{21}, \text{C}_{22}, \text{C}_{23}, \text{C}_{24}, \text{C}_{25}, \text{C}_{26}, \text{C}_{27}, \text{C}_{28}, \text{C}_{29}, \text{C}_{30}, \text{C}_{31}, \text{C}_{32}$ — 2,0 мкф.

Fig. 64. Amplitude characteristics of cascade/stage with the nonlinear feedback with of $E_{cm, \text{neg}} = 0,2 \text{ V} = \text{const}$ and $R_{o, c} = \text{var.}$

Key: (1). V . (2). $R \mathcal{N}$.



The scatter of the value of the currents of separate diodes must not exceed 50/o.

If for a decrease in the initial resistor/resistance of the nonlinear cell/element of aaaaaa they connect in parallel two diode, then them they select as follows. Measure the resistor/resistances of diodes in forward direction with voltage +1c, and then these diodes bank in pairs so that the resistor/resistances of pairs would be identical.

Example. Let us assume that six diodes of the type of D2E with voltage 1 in have the following resistor/resistances: the first is $R_1 = 220$ ohm; the second - $R_2 = 240$ ohm; the third is $R_3 = 210$ ohm; the fourth - $R_4 = 2555$ ohm; the fifth is $R_5 = 245$ cmv of the sixth - $R_6 = 227$ ohm. In order that the pairs of diodes would have identical resistor/resistances, necessary to combine the first diode with the fifth, second with the sixth, the third with the fourth; the first pair - $R_{1,5} = 116$ ohm; the second pair - $R_{2,6} = 116.5$ ohm; the third pair - $R_{3,4} = 115$ ohm. At this selection of diodes, the recurrence of the parameters of nonlinear cell/elements is obtained sufficiently good.

Figures 64 and 65 give the experimental amplitude characteristics of one nonlinear cascade/stage, assembled on a tube of the type of 6J5P for:

- 1) the constant value of displacement on the nonlinear

cell/elements of the $E_{cm_{\text{нел}}} = 0.2$ v and of the different values of the resistor/resistance of the feedback of $R_{o,c} = 1.5; 3; 4$ and $6 \text{ k}\Omega$ (resistor/resistance R_3 in the diagram of Fig. 63);

2) the constant zncheniya of the resistor/resistance of the $R_{o,c} = 3 \text{ k}\Omega$ and different values of the voltage of $E_{cm_{\text{нел}}} = 0.3; 0.25; 0.2$ and 0.15 V .

From figures it is evident that with an increase in the resistor/resistance of $R_{o,c}$ and a decrease in the voltage of $E_{cm_{\text{нел}}}$ the range LAX increases, but in this case decreases the maximum factor of amplification of cascade/stage K_1 . Changing the values of the resistor/resistance of $R_{o,c}$ and voltage of $E_{cm_{\text{нел}}}$ possible easily and rapidly to obtain the amplitude characteristic of cascade/stage, necessary for the successive work of nonlinear cascade/stages.

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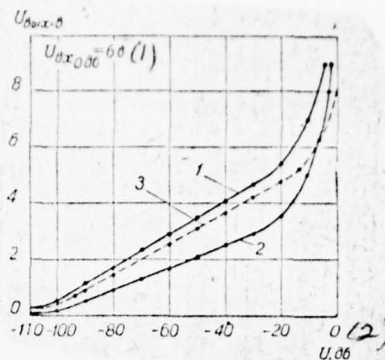
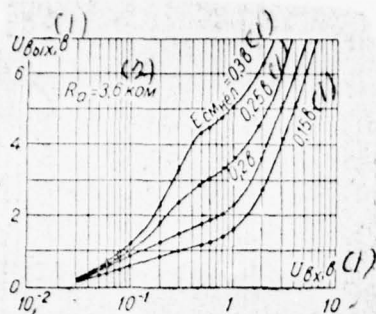


Fig. 65. Amplitude characteristics of cascade/stage with the nonlinear feedback with of $R_{D,c} = 3 \text{ k}\Omega = \text{const}$ and $E_{cm,нел} = \text{var.}$

Key: (1). V . (2). dBm

Fig. 66. Amplitude characteristics of logarithmic video amplifier with the nonlinear feedback:

$$\begin{aligned}
 1 - E_{cm,нел,1} &= +0.19 \text{ e}; \\
 E_{cm,нел,1,4} &= -0.2 \text{ e}; E_{cm,нел,2} = -0.21 \text{ e}; \\
 2 - E_{cm,нел,1,3} &= +0.17 \text{ e}; \\
 E_{cm,нел,2,4} &= -0.18 \text{ e}; \\
 3 - E_{cm,нел,1,3} &= +0.22 \text{ e}; \\
 E_{cm,нел,2,4} &= -0.23 \text{ e}.
 \end{aligned}$$

Key: (1). V . (2). dB .

Figure 66 shows the amplitude characteristics of the amplifier (unbroken curves), the printsipil'nya of diagrams of which is given the n of Fig. 63. Khrkteristiki correspond to the different values of bias voltages on the nonlinear cell/elements, indicated under figure.

On the basis of the conducted theoretical and experimental investigations of logarithmic amplifier with nonlinear cell/elements in the cathode circuits of amplifier stages it is possible to make the following conclusions:

1. Range the LAX of one cascade/stage can be obtained to 28-30 dB.

2. If as nonlinear cell/elements are applied germanium diodes of the type of DG-Q or D2, then the greatest range the LAX of cascade/stage is obtained during the bias voltages of $E_{cm_{ger}} = 0.1 - 0.15$ v and the resistor/resistances of the feedback of the $R_{o,c} = 3 - 6$ *kohm*. The LAX of cascade/stage begins with the input voltage of $U_{BX} = 30 - 80$ mV.

3. Slope/transconductance the LAX of amplifier and its range it is very easy to change by changing the stress of $E_{cm_{ger}}$.

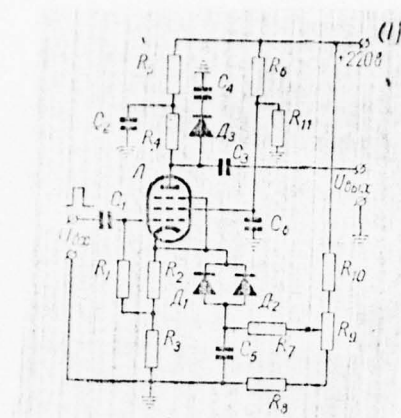


Fig. 67. Diagram of one of the versions of the application of voltage of displacement to nonlinear cell/elements from of anode power supply.

Key: (1). ✓.

4. In n-cascade amplifier it is possible to carry out a strictly successive work of nonlinear cascade/stages, which makes it possible in four-stage amplifier to obtain LAX in the range to 80-100 dB with accuracy 2-3o/o. In this case, the amplifier is not overloaded, it does not lose the maximum sensitivity and amplifies without clipping to 10-15 in.

5. The amplitude characteristic of amplifier is very stable during a change of the repetition frequency and pulse duration in limits of $F = 500-5000$ Hz $t_n = 0.3-10$ μ s.

6. Any deflections of the amplitude characteristic of n-cascade amplifier, caused by ageing and the exchange of tubes, can be removed by a change in the bias voltages on nonlinear cell/elements into the cascade/stages in which were replaced the tubes.

7. The essential advantage of diagram is a good recurrence of the parameters of the amplifiers, assembled by this diagram.

Asymmetric amplifier has the following deficiency/lacks:

1. It amplifies according to logarithmic law the momentum/impulse/pulses only of any one polarity. The momentum/impulse/pulses of another polarity, in particular parasitic reverse/inverse overshoots, are amplified according to linear law, which leads to excessive rostuparazitnykh reverse/inverse overshoots at the output of amplifier during an increase in the input signal.

This deficiency/lack can be removed, by including the diodes, which cut reverse/inverse overshoots, after transient capacitance/capacity (in Fig. 63 diodes D_5 , D_6 , D_7 , D_8) or to it (diode D_3 in Fig. 67).

It is most expedient to switch on the cutting diodes to transient capacitance/capacity, since in this case the parasitic reverse/inverse overshoot of nonlinear cascade/stage will be smallest and equal to the parasitic reverse/inverse overshoot of linear cascade/stage.

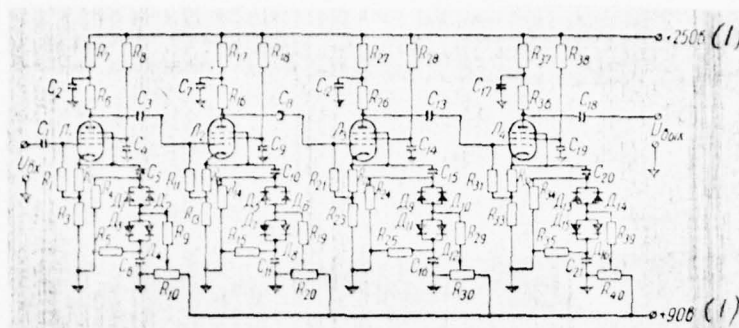


Fig. 68. Schematic diagram of symmetrical logarithmic video amplifier with the nonlinear feedback: L_1, L_2, L_3, L_4 - 6J5P; D_1, D_2, \dots, D_{16} - D2J; $R_1, R_{11}, R_{21}, R_{31}$ - 56 $k\Omega$; $R_2, R_{12}, R_{22}, R_{32}$ - 120 $k\Omega$; $R_3, R_{13}, R_{23}, R_{33}$ - 3 $k\Omega$; $R_6, R_{16}, R_{26}, R_{36}$ - 4.3 $k\Omega$; $R_7, R_{17}, R_{27}, R_{37}$ - 3.3 $k\Omega$; $R_8, R_{18}, R_{28}, R_{38}$ - 27 $k\Omega$; $R_{10}, R_{20}, R_{30}, R_{40}$ - 22 $k\Omega$; $R_4, R_5, R_9, R_{14}, R_{15}, R_{19}, R_{24}, R_{25}, R_{29}, R_{34}, R_{35}, R_{39}$ - 15 $k\Omega$; $C_1, C_3, C_8, C_{13}, C_{18}$ - 0.1 μF ; C_2, C_7, C_{12}, C_{17} - 2.0 μF ; C_4, C_9, C_{14}, C_{19} - 10.0 μF ; $C_5, C_6, C_{10}, C_{11}, C_{15}, C_{16}, C_{20}, C_{21}$ - 30.0 μF .

Key: (1) - \checkmark .

It should be noted that the separating capacitance/capacity C_4 to a certain degree is correcting (decreasing) reverse/inverse parasitic overshoot, since its effect on the transient processes, which take place in cascade/stage after the break-down of momentum/impulse/pulse, to the opposite influence of the transient capacitance/capacity C_3 .

2. For the creation of bias voltage on nonlinear cell/elements, is required direct/constant voltage of both polarity. This deficiency/lack can be removed, if the bias voltage of $E_{cm_{neg}}$ is created because of a difference in direct/constant voltages, removed from the resistor/resistance of feedback ($R_3 + R_2$) and of voltage divider R_8 , R_9 and R_{10} (Fig. 67). By changing the value of resistor/resistance R_9 , on nonlinear cell/element it is possible to create the necessary both positive and negative bias voltage. In this case is required the stabilized voltage of anode power supply. Resistor/resistances R_8 and R_{10} protect semiconductor diode from the incidence/impingement on it of high direct/constant voltage during the complete derivation of potentiometer R_9 to one or another side.

Both indicated deficiency/lacks are absent from the symmetrical logarithmic video amplifier when in the cathodes of amplifier stages are included nonlinear cell/elements by diagram in Fig. 36.

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Figure 68 depicts the schematic diagram of four-stage symmetrical logarithmic video amplifier, while Fig. 66 - its amplitude

characteristic (is curve 3). Upon the inclusion into the anode circuits of the cascade/stages of the cutting detectors reverse/inverse overshoot at the output of multistage amplifier at the end of the logarithmic range 70-80 dB is not virtually noticeable.

Deficiency/lacks in the symmetrical logarithmic video amplifier are the more complex amplifier circuit and the need for the large number of nonlinear cell/elements. As is known, with an increase in the number of nonlinear cell/elements, the reliability of the work of amplifier decreases.

Obtaining LAX in video amplifier by the addition of the voltages from the output/yields of linear cascade/stages.

The schematic diagram of the two-stage video amplifier in which the LAX is obtained by the addition of voltages from the output/yields of linear cascade/stages, is depicted on Fig. 69. In order that the voltages, which enter from the output/yields of amplifier stages UK_1 and of the UK_2 , assembled on tubes L_1 and L_2 , would store/add up themselves at the output of amplifier, in parallel to each amplifier stage was connected cascade/stage with the factor of amplification of $K_n \approx 1$. Supplementary cascade/stages are intended for a transmission (repetition) without distortion of the signals, which enter their inputs. Because of this their amplification factors must be equal to unity. Let us agree such cascade/stages to call repeaters. Unlike cathode follower, they

change the phase of the transmitting voltage on 180° . The repeaters, assembled on tubes L_3 and L_4 , let us designate respectively P_1 and P_2 .

Amplifier stages and repeaters interconnected in pairs. A decrease in the factor of amplification of repeater to unity is achieved by means of the inclusion into the cathode circuit of the tube of the high resistor/resistance of the feedback of $R_{o.c}(R_{15} + R_{14})$ in the cathode of tube L_3 and $R_{18} + R_{19}$ in the cathode of tube L_4 . The necessary condition is the ability of repeater to pass sufficiently large signals.

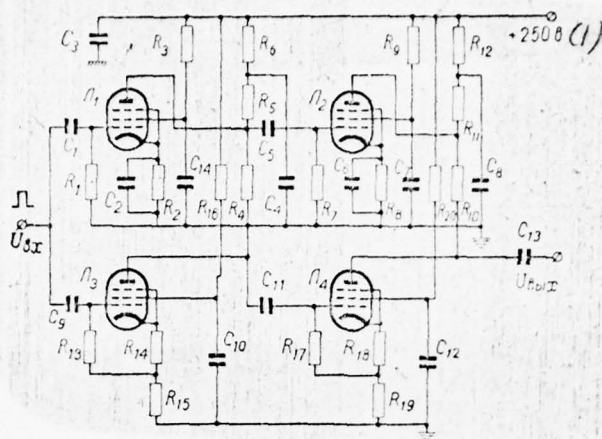


Fig. 69. The schematic diagram of the logarithmic video amplifier in which the LAX is obtained by the addition of the voltages: L_1, L_2, L_3 - 6J5P; L_4 - 6K4P; R_1, R_7, R_{13}, R_{17} - 56 comas; R_2, R_8 - 110 ohm; R_3 - 25 kohm; R_4, R_{10} - 2.2 kohm; R_5, R_{11} - 1 kohm; R_6, R_{12} - 3.3 kohm; R_9 - 75 kohm; R_{16}, R_{20} - 33 kohm; R_{14} - 240 ohm; R_{15}, R_{19} - 2 kohm; R_{18} - 500 ohm; $C_1, C_5, C_9, C_{11}, C_{13}$ are 0.1 μ F; $C_2, C_3, C_4, C_6, C_7, C_8, C_{10}, C_{12}$ - 2.0 μ F.

Key: (1). \checkmark .

For this, follows to increase the resistor/resistance of $R_{0,c}$ so as the more the $R_{0,c}$ to the facts with large signals it is absent the overloading of repeater. But of a considerable increase in the resistor/resistance of $R_{0,c}$ the factor of amplification of repeater stanvitsya less than unity. For the preservation/retention/maintaining of K_0 it is necessary to increase anode resistor/resistance. This leads to the fact that the remya of the establishment of the momentum/impulse/pulse of t_{y_1} at the output/yield of amplifier stage considerably increases. In order that time of t_{y_1} would be small, the anode resistor/resistance of amplifier stage is undertaken as part of the anode resistor/resistance of repeater. Thus, for instance, in the diagram, depicted on Fig. 69, by the anode resistor/resistance of the cascade/stage of UK_2 is the resistor/resistance R_{11} , and the anode resistor/resistance of repeater P_2 - the sum of resistor/resistances $R_{11} + R_{10}$. After input process of the amplifier of positive pulses on the input of repeater P_2 (tube L_4) enter negative signals. In order that repeater would pass large negative signals, it must be fulfilled with variable slope electron tube in the zone of negative stresses (tube of the type of 6K4P).

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Remaining amplifier stages it is expedient to fulfill with the tubes, which have characteristic with sharp as the cutoff of anode current (tube of the type of 'zheP, 6J5P, 6J9P, etc.).

Let us examine the work of diagram. The entering on the input of

amplifier small stress is amplified linearly by the cascade/stages of UK_1 and UK_2 with the maximum amplification factor. With an increase in the input voltage, the last/latter cascade/stage UK_2 gradually is impregnated and its amplification factor decreases. The complete saturation of the cascade/stage of UK_2 occurs upon reaching by the input voltage of the determined level on which the cascade/stage ceases to amplify. Voltage from the output/yield of the cascade/stage of UK_1 in this case transmits to the output/yield of repeater P_2 with the factor of amplification of $K_{11} = 1$ and store/adds up itself with the voltage, which enters from the output/yield of the cascade/stage of UK_2 . Subsequently with an increase in the input signal, is overloaded the cascade/stage UK_1 . Then voltage from the input of amplifier transmits to output/yield by repeaters P_1 and P_2 and store/adds up itself with the voltages, which enter from the output/yields of cascade/stages UK_1 and of UK_2 . Since the cascade/stages of UK_1 and UK_2 during an increase in the input voltage are overloaded gradually, as a result of the addition of the voltages from the output/yields of linear cascade/stages is obtained the logarithmic dependence between the output U_{out} and the input U_{in} by voltages.

With the appropriate podobore of the mode/conditions of repeaters and amplifier stages it is possible to obtain the sufficiently precise logarithmic dependence between of U_{out} and U_{in} . In amplifier the mode/conditions of repeaters are fitted in such a way that the repeater P_2 passes negative signals to 15 into with the transmission

factor of $K_n = 1$, signals to 60 C - from $K_n = 0,5$ and signals to 10
into from $K_n = 0,3$; signals to 30 C - from $K_n = 0,5$ and signals to 60 C
- from $K_n = 0,35$.

For a decrease in the deflection of experimental characteristic from accurately logarithmic, it is necessary that the overloading of amplifier stages would begin with lesser input voltage. For this purpose, the screen-grid voltage of tubes L_1 and L_2 is taken 80 in. In this case, the factor of amplification of the linear cascade/stages $K_1 = K_2 = 8$.

Figure 70 depicts the experimental characteristic of two-stage amplifier. from the figure one can see that the range LAX is equal to 60 dB.

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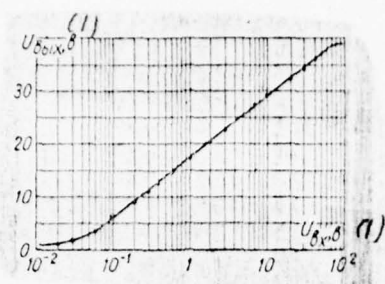


Fig. 70. Amplitude characteristic of logarithmic amplifier with after the dovatel'nym addition of voltages.

Key: (1). in.

In this case, the deflection of experimental characteristic from accurately logarithmic does not exceed 5c/o. The more precise IAX of amplifier can be obtained, by increasing the number of cascade/stages. But in this case becomes complicated the adjustment of logarithmic amplifier, since grow/rises the number of adjustable repeaters.

The exchange of tubes in amplifier causes the supplementary deflections of experimental characteristic from accurately logarithmic. These deflections can be removed, by changing the value of the resistor/resistances of feedback in repeaters.

It is possible to note the following advantages of the diagram in question:

1. The stability of the amplitude characteristic of this amplifier is determined in essence by the stability of the parameters of tubes and is higher as compared with the stability of the amplitude characteristics of the logarithmic amplifiers, in which are applied pluprovodnikovye diodes.

2. The absence of delay line which is necessary in obtaining IAX in UPCh by consecutive detection. The role of delay line in this case fulfills cascade/stage-repeaters.

Deficiency/lacks in the diagram:

1. Are required two amplifier tubes to each cascade/stage, which leads to an increase in the overall sizes of amplifier.

2. As a result of the overloading of amplifier stages, is absent the instantaneous restoration/reduction of the maximum sensitivity of amplifier after the break-down of large signal.

If to the input of two-stage amplifier enters positive signal, then is overloaded the first cascade/stage and the recovery time of the sensitivity of amplifier in essence is determined by the recovery time of the sensitivity of this cascade/stage. For the elimination of the overloading of the first cascade/stage, it is expedient at the input of amplifier to supply diode limiter.

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§ 2. Logarithmic low-frequency amplifiers (UNC [- low-frequency amplifier]).

For the amplification of the fluctuations of audio frequency it is possible to utilize bipolar logarithmic amplifiers with the nonlinear divider/denominators and with nonlinear feedback in which the amplification changes virtually instantly in accordance with the instantaneous value of signal. Because of this during the amplification of harmonic oscillations by logarithmic amplifiers with instantaneous gain control are observed signal distortions which develop themselves in the flattening of the sinusoidal form of curve. This leads to the fact that with an increase in the signal level changes the relationship/ratio between the amplitude, average and

effective values of the intensive signal. In certain metering equipment in which are applied the logarithmic amplifiers, these distortions are inadmissible.

The amplified harmonic oscillations by amplifier are not distorted, if amplification is changed because of a change in the mutual conductance of tubes on the low signal levels in accordance with its average value. Such amplifiers include the logarithmic amplifiers with automatic gain control. The time constant of the circuit of adjustment is selected in accordance with the requirements, imposed for equipment/device, into composition of which the tiny of characteristic the controlling voltage can be supplied to the managers, to pentode or to the screen grids of tubes.

Logarithmic UNC with AGC on the control electrodes of tubes.

In logarithmic UNC with AGC on the control electrodes of tubes, schematic diagram of whom is depicted on Fig. as 71, are applied the amplifier tubes of 6K4P with the elongated characteristic. In this amplifier it is possible to obtain the dynamic range LAX, which is necessary to one cascade/stage, 30-35 dB and small distortions of harmonic oscillations.

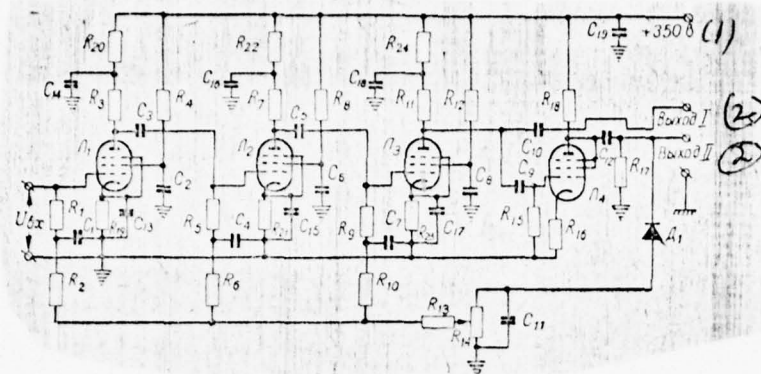
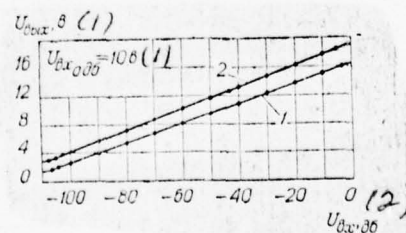


Fig. 71. Schematic diagram of logarithmic UNC with AGC on the control electrodes of the tubes: L_1, L_2, L_3 - 6K4P; $R_1, R_5, R_9, R_{15}, R_2, R_{10}, R_{13}$ - 390 comas; R_3, R_7, R_{11} - 10 comas; R_4, R_8, R_{12} - 91 comas; R_{14}, R_{17} - 51 comas; R_{16} - 200 ohm; $C_3, C_5, C_{10}, C_9, C_{11}, C_{12}$ - 0.1 mkzh; C_2, C_6, C_8 - 1 μ F; R_{18} - 3.9 comas; C_1, C_4, C_7 - 0.2 μ F; D_1 - D2E, $C_{13}, C_{14}, C_{15}, C_{16}, C_{17}, C_{18}, C_{19}$ - 1 mkzh.

Key: (1). in. (2). output/yield.

Fig. 72. Amplitude characteristics of logarithmic UNC with AGC: 1 - on the control electrodes of tubes; 2 - on the pentode grids of tubes.

Key: (1). in. (2). vkhdb.



The circuit of adjustment (feedback loop) consists of wideband amplifier on tube L₄, the type of 6J1P with negative feedback and the detector, assembled on a germanium diode of the type of DG-07. Amplifier in the circuit of adjustment must have a passband of frequencies considerably more the passband of the adjustable multistage amplifier (logarithmic amplifier) in order that the gain control would be uniform in all frequency band, passed by logarithmic amplifier. The load of detector (resistor/resistance R₁₄ = 51 ohms) is selected from the condition of obtaining the sufficiently slow response of the charge of the capacitance/capacity of the load of detector C₁₁. The cell/elements of filters R₂, R₆, R₁₀, C₁, C₄ and C₇ are selected so that the time constant of filters would be considerably more than the period of lowest frequency, passed logarithmic amplifier. The controlling voltage from potentiometer (resistor/resistance R₁₄) is supplied to the control electrodes of all three tubes.

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By moving the wiper, possible fast enough to fit the necessary amplitude characteristic of amplifier. Output voltage can be remove/taken from the load of the third cascade/stage (output/yield I) or from the load of the fourth cascade/stage (output/yield II) depending on the type of indicator and its sensitivity. Experimental amplitude characteristic on output/yield I is depicted on Fig. 72 (is curve 1). Dynamic range LAX to 100 dB with an accuracy to 20/o. Slope/inclination and dynamic range LAX can be changed, by moving the

wiper.

Logarithmic UNC with AGC on the pentode grids of tubes.

During gain control on control electrode, the tube must have the elongated characteristic with alternating/variable slope/transconductance. A deficiency/lack in such tubes is a comparatively small mutual conductance. Furthermore, with sufficiently large signals AGC on control electrode do not provide the undistorted amplification of signal. Tubes with large slope/transconductance, as a rule, have short characteristic with sharp as the cutoff of anode current. Effective AGC in such tubes is obtained during the supplying of the controlling voltage on the pentode or screen grids of tube.

The smallest distortions of the form of the amplified signal are observed during the supplying of the controlling voltage on pentode grid. This is explained by the fact that the mutual conductance of tube in this case decreases because of drift down and the linear section of characteristic virtually does not change. During the correct selection of operating point it is possible to obtain amplification from logarithmic law in wide dynamic s-band the preservation/retention/maintaining of sinusoidal waveform. Schematic diagram UNC with AGC on pentode grids is depicted on Fig. 73, and its amplitude characteristic - on Fig. 72 (is curve 2).

Amplification in diagram is regulated as follows. The feed currents of tubes, flow/lasting through resistor/resistance R_3 , create on it voltage drop on the order of 100 in. Thus, the potential of the cathodes of amplifier tubes L_1 , L_2 and L_3 earth referenced is equal to 100 in.

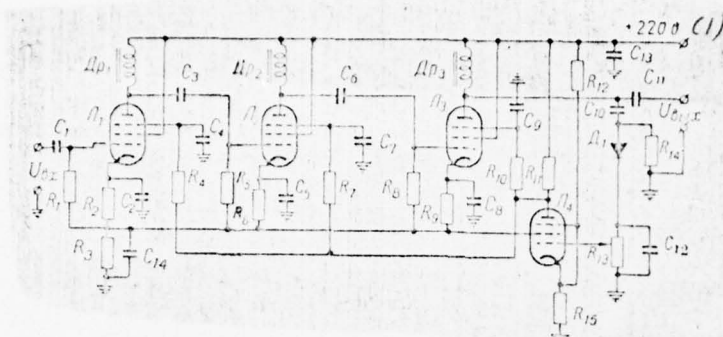


Fig. 73. Schematic diagram of logarithmic UNC with AGC on the pentode grids of the tubes: L_1, L_2, L_3, L_4 - 6J5P; R_1, R_5, R_8 - 51 comas; R_2, R_6, R_9 - 100 ohm; R_3 - 3 comas; R_4, R_7, R_{10} - 100 comas; R_{11} - 120 comas; R_{13}, R_{14} - 75 comas; R_{12} - 220 comas; R_{15} - 500 ohm; $C_1, C_3, C_6, C_{10}, C_{11}$ - 0.1 μF ; C_4, C_7, C_9, C_{12} - 0.2 μF ; $C_2, C_5, C_8, C_{13}, C_{14}$ - 10.0 μF .

The pentode grids of tubes are connected through the resistor/resistances of filters with the anode of the tube L_4 on which is assembled the dc amplifier (UPT). In order that the potential of the pentode grids of tubes L_1 , L_2 and L_3 would be equal to zero relative to cathodes, the potential of the anode of tube L_4 earth referenced must be equal to the potential of the cathodes of tubes L_1 , L_2 and L_3 , i.e., 100 in. The detected voltage is remove/taken from potentiometer R_{13} and approaches the control electrode of tube L_4 . With an increase in the signal level, the detected voltage also increases, which causes a decrease in the potential of the anode L_4 and, consequently, also the potential of the pentode grids of amplifier tubes. By changing the position of the arm of potentiometer R_{13} and the factor of amplification of UPT, it is possible sufficient easily to obtain the required amplitude characteristic of amplifier. The constant of gain control is determined by the time constants of the load circuit of detector and filters in the circuits of pentode grids. During gain control, the potential of the screen grids of tubes must be constant. For this purpose, the screen grids of tubes are connected directly with of anode power supply.

Range the LAX of three-stage amplifier can be obtained to 100-110 dB with the accuracy of order 2-3o/o.

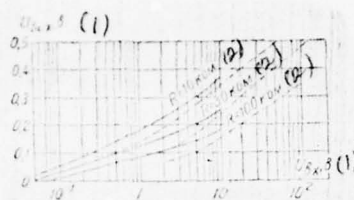


Fig. 74. Amplitude characteristics of the passive logarithmizing chain/networks: — D2E; - - - - D9A.

Key: (1). \checkmark . (2). *Rohm*

Logarithmic UNC with AGC on screen grids can be assembled by analogous diagram. The dynamic range LAX, which is necessary to one cascade/stage, also can be obtained to 30-35 dB.

§ 3. Logarithmic direct-current amplifiers (UPT).

For logarithmic operation of direct current and the voltages can be used passive nonlinear chain/networks (Fig. 47) and the amplifier stages, depicted on Fig. 48 and 50.

Figure 74 shows the amplitude characteristics of passive nonlinear chain/networks when using as the nonlinear cell/elements of germanium diodes of the type of D2E and D9V. Characteristics are given for the different values of series-connected resistor/resistance R. By applying diodes of the type of DG-Q and DY, it is possible to obtain the amplitude characteristics, analogous to characteristics in the case of using diodes of the type D2. Figure 74 shows that, utilizing prodiodov of the type D2. Figure 74 shows that, by utilizing the simplest nonlinear chain/network, it is possible to obtain LAX in the range to 30-35 dB (dicde D2E, R = 100 comas). Works [27] and [41] shows that range the LAX of passive chain/network can be considerably expanded, by applying the special compensating source.

A deficiency/lack in the passive nonlinear chain/networks is the low transmission factor. This deficiency/lack is absent from the logarithmizing cascade/stages, assembled by diagrams in Fig. 48 and 50. For a diagram with the use of grid currents, it is necessary to

apply the tube, which has large grid current with negative voltages, for example a tube of the type of the 6J1P, the grid characteristics of $i_g = f(U_g)$ of which are given in Fig. 49. The aforesaid is confirmed by Fig. 75, on which are depicted the amplitude characteristics of UPT, assembled on the tube of 6J1P by diagram in Fig. 50.

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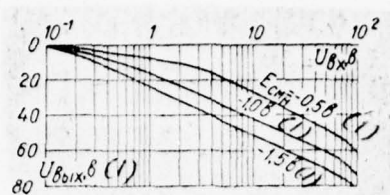


Fig. 75. Amplitude characteristics of UPT with the use of grid currents.

Key: (1). V_i

Characteristics are given for different initial bias voltages on the grid of the E_{cmH} with of the $R_a = 15 \text{ KOM}$; $R_c = 50 \text{ KOM}$ and an $U_a = U_s = 120 \text{ v}$. For obtaining zero on output/yield in the absence of signal on the input into the cathode circuit of tube included compensating voltage of $E_K = 120 \text{ v}$. Figure 75 shows that the dynamic range the LAX of cascade/stage with the use of grid currents can be obtained to 50 dB. Range and slope/inclination LAX, the level of the input voltage with which begins the LAX, and the maximum factor of amplification of cascade/stage can be changed by changing the value of the grid resistor of the R_c , of the anode resistor/resistance of R_a and initial bias voltage of E_{cmH} .

UPT from LAX in wide dynamic range also can be fulfilled with AGC on screen and pentode grids. The diagram of the cascade/stage of UPT with AGC in pentode grid differs from the diagram of stage of the amplifier, depicted on Fig. 73, only fact that into UPT are absent the transient capacitance/capacities. During the appropriate selection of the amplifier gain in the circuit of adjustment dynamic range the LAX of one cascade/stage of UPT with AGC in pentode or screen grids can be obtained to 60-80 dB with accuracy 2-3o/c.

Special attention into UPT from LAX it is necessary to give the stabilization of operating point. For this purpose, it is expedient the first cascade/stage to execute linear with large amplification factor and with the stabilization of operating point.

The block diagram multistage the UPT in which the LAX is obtained

over a wide range according to the method of the addition of voltages, is shown in Fig. 76.

As the logarithmizing equipment/device (LU) it is possible to utilize either the passive logarithmizing chain/network or the logarithmizing cascade/stage.

The work of amplifier is analogous to the work of the diagram, depicted on Fig. 14. In order that the taken the logarithm signal cephasally store/add up itself on the overall load of R_n , LU were connected to the output/yields of even amplifier stages.

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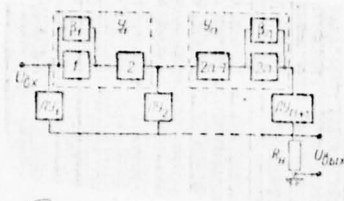


Fig. 76.

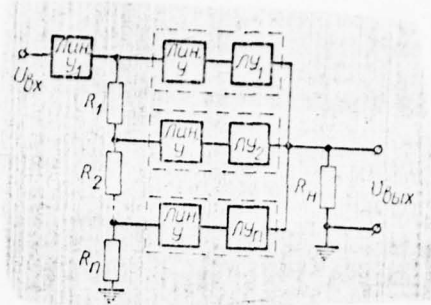


Fig. 77.

Fig. 76. The block diagram logarithmic multistage the UPT: 1 - linear amplifier stage with the stabilization of operating point; 2, 3, ..., 2n - linear cascade/stages without the stabilization of operating point; β is a feedback loop; LU - the logarithmizing equipment/device.

Fig. 77. Block diagram logarithmic UPT with linear divider/denominator.

A precise LAX of amplifier is obtained when factor of amplification K_1 component/link Y , which consists of two cascade/stages, is numerically equal to the dynamic range of the LAX of the logarithmizing equipment/device D_1 , and the amplitude characteristic of the latter is described by expressions (II.49) and (II.51). In this case dynamic range the LAX of the amplifier

$$D = D_1^{n+1},$$

where D_1 is dynamic range LU.

The value of the voltage of U_{bx} on the input LU, upon which it begins to logarithmize equipment/device, is assigned by the appropriate bias voltage, applied to control electrode. Constancy of output potential LU after having emerged from the logarithmic operating mode of the obespechivaetsvtorcgo cascade/stage of the corresponding component/link Y . For the ustoychivoyraboty multistage UPT one of the two cascade/stages of each amplifying circuit Y is enveloped by negative feedback. Furthermore, by negative feedback can be enveloped entire amplifier.

The block diagram of another version multistage UPT from LAX is depicted on Fig. 77. In this diagram the pcccherednost' of arrival into logarithmic operating mode LU is determined by the divider/denominator, which consists of the linear resistor/resistances of R_1, R_2, \dots, R_n . In this case, must occur the following relationship/ratio:

$$\frac{R_1 + R_2 + \dots + R_n}{R_2 + R_3 + \dots + R_n} = \frac{R_2 + R_3 + \dots + R_n}{R_3 + R_4 + \dots + R_n} = \dots = \frac{R_{n-1} + R_n}{R_n} = D_1,$$

where n is a number LU.

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For obtaining precise by LAX over a wide range the common amplitude characteristics of the logarithmizing channels (luxes), which consist of linear amplifiers and IU, must be described by equations (II-49) and (II-51). The constancy of output potential of each IU after having emerged of it from logarithmic operating mode is provided by the limiting action of the amplifier stages, confronting LU. The stabilization of operating point it is expedient to execute in the linear cascade/stage, connected before the divider/denominator. The factor of amplification of this cascade/stage must be sufficiently large.

A deficiency/lack in the examined diagram is the comparatively small maximum amplification factor, which is equal to the product of the factors of amplification of the first cascade/stage and logarithmizing channel. For an increase in the maximum coefficient of amplifier, it is necessary to increase factor of amplification luxes, which complicates diagram.

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Chapter Four

SELECTIVE LOGARITHMIC AMPLIFIERS.

For the amplification both of the modulated and not modulated signals of high frequency, are applied the selective amplifiers, which are divided by two groups: 1). tuned amplifiers with the single-circuit inclined or mutually detuned cascade/stages; 2). the band-pass amplifiers, which consist of the cascade/stages, in the circuits of which are included the band-pass filter.

The block diagrams of the different types of selective amplifiers are given in work [25].

Concrete/specific/actual schematic diagrams of logarithmic selective amplifiers, their pros and cons must be selected to examine according to the method of obtaining LAX.

§1. Obtaining LAX in selective amplifiers by changing the amplification factor.

Logarithmic selective amplifier with nonlinear cell/elements in anode circuits.

In multistage logarithmic selective amplifier in the shunting of the anode loads of cascade/stages by variable cell/elements it is most expedient to apply the amplifiers, which consist of the cascade/stages, in anode circuits of which are included single or two-circuit filters.

In the logarithmic amplifiers, made on pairs or sets of three of mutually detuned cascade/stages, appear the distortions of the form of resonance curve, what is an essential deficiency/lack in these amplifiers. For the symmetry of the resonance characteristic of logarithmic amplifier with the mutually resonant cascade/stages pair it is necessary that both cascade/stages of pair would have the identical coefficient of amplification with any input voltage.

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However, in work in nonlinear mode/conditions, the factor of amplification of cascade/stage depends on signal amplitude. Since

signal amplitudes in two adjacent cascade/stages are always different, also amplification factors not identical, which causes the dissymmetry of resonance characteristic. For obtaining symmetrical resonance characteristic in this amplifier, it would be necessary to apply the mode/conditions of simultaneous work the vapors (or sets of three) of cascade/stages in linear and nonlinear mode/conditions. In this case, the amplitude characteristics of separate cascade/stages the vapors (or sets of three) must be different and, therefore, in them necessary to apply different nonlinear cell/elements. According to the conditions of production and operation this netselessobrazno.

For the sake of simplicity in production and operation of logarithmic selective amplifier, it is expedient in all cascade/stages to utilize identical nonlinear cell/elements.

The schematic diagram of four-stage logarithmic tuned amplifier is shown in Fig. 78. LAX in amplifier is obtained by the shunting of the single plate circuits, tuned to frequency $f_0 = 20$ MHz, by germanium diodes of the type of D2E (diodes D_1, D_2 etc.). From potentiometers R_{20} and R_{21} to diodes, are given the odinaovye in value zairayushchiye voltages of $E_{\text{заян}} = \pm 0,1$ V. For obtaining the necessary amplitude characteristics of cascade/stages consecutively with nonlinear cell/elements in the second, third and fourth cascade/stages are included active linear resistor/resistances on 240 ohms (resistor/resistances R_{10}, R_{14}, R_{18} etc.). The amplitude characteristic of the last/latter cascade/stage is depicted on Fig.

79. Maximum factor of amplification of cascade/stage $K_1 = 8$. Figure 79 shows that the characteristic completely satisfies the requirements of the successive work of cascade/stage, since are fulfilled equalities $D_1 = K_1 = 8$ and $b = 1$, where b is a differential factor of amplification of cascade/stage in quasi-linear operating mode

$$(U_{BX_1} = 0,01 \text{ V}; U_{BX_1} = 0,08 \text{ V}).$$

In the decibels of

$$D_{1(\text{dB})} = K_{1(\text{dB})} = 18 \text{ dB}.$$

The amplifier, depicted on Fig. 78, has the following parameters: the maximum factor of amplification $K_0 = 4.1 \cdot 10^3$ or of

$$K_{(\text{dB})} = 72,2 \text{ dB, passband of work in linear conditions } \Delta f = 0.4$$

MHz.

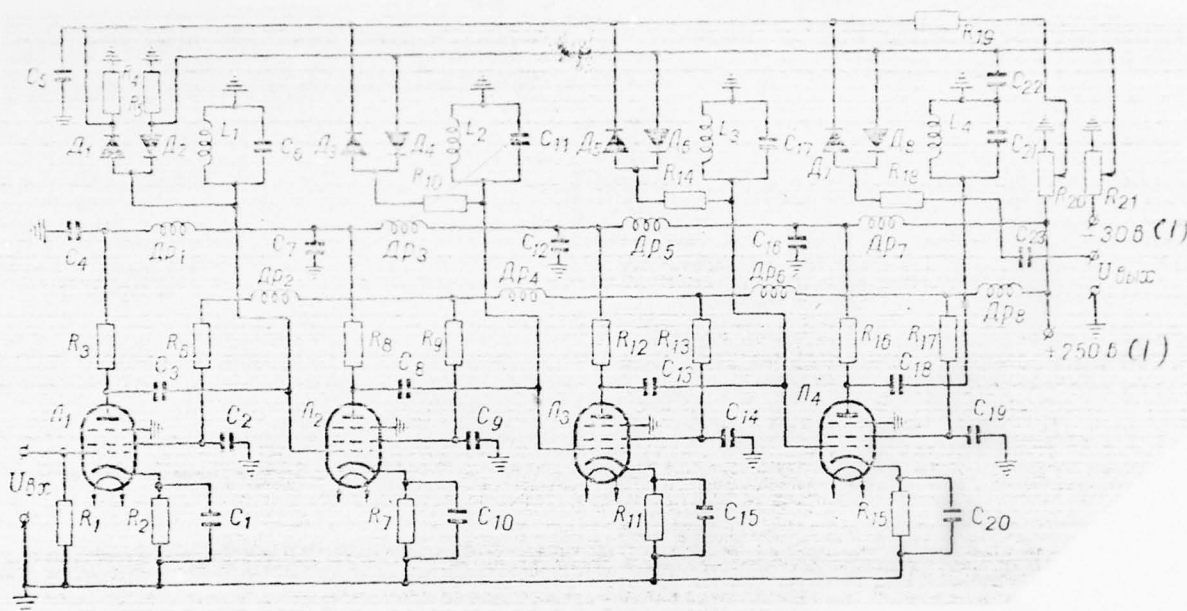


Fig. 78. The schematic diagram of resonance logarithmic amplifier with nonlinear cell/elements for the anode target/purposes of the cascade/stage: R_1 are 75 ohm; $R_2, R_4, R_5, R_7, R_{11}, R_{15}$ is 100 ohm; R_3, R_8, R_{12}, R_{16} - 4.7 comas; R_6, R_9, R_{13}, R_{17} - 6.2 comas; R_{10}, R_{14}, R_{18} - 240 ohm; R_{20}, R_{21} - 68 comas; R_{19} - 33 comas; $D_1, D_2, \dots, D_7, D_8$ - D2E; L_1, L_2, L_3, L_4 - 6K4P; $S_6, S_{11}, S_{17}, S_{21}$ - 15 nf; $S_1, S_2, S_4, S_5, S_7, S_9, S_{10}, S_{12}, S_{14}, S_{15}, S_{16}, S_{19}, S_{20}, S_{22}$ - 6800 nf; $S_3, S_6, S_{13}, S_{18}, S_{22}$ - 100 nf.

Key: (1). V.

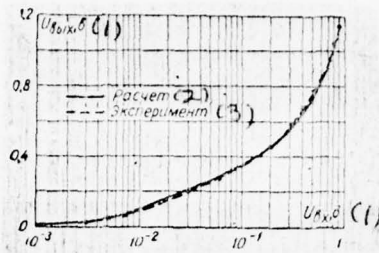
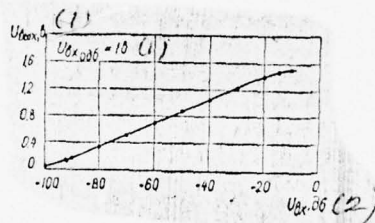


Fig. 79. Amplitude characteristic of cascade/stage with the plate load, shunted by nonlinear cell/elements.

Key: (1). V. (2). Calculation. (3). V.

Fig. 80. Amplitude characteristic of resonance logarithmic amplifier.

Key: (1). V. (2). dB.



The amplitude characteristic of amplifier is given in Fig. 80, from which it is evident that the LAX begins with the input voltage of

$$U_{\text{вхн}} = 2,5 \cdot 10^{-6} \quad \text{V and terminates with}$$

Dynamic range the LAX of amplifier composes $D = 70$ dB instead of the calculated $D_{(06)} = 4D_{1(06)} = 72$ dB, which indicates the strictly successive work of cascade/stages. Accuracy LAX in all range 70 dB of order 2-3o/o. Everything said in §1 chapter III about the possibilities of obtaining LAX in aperiodic amplifiers by the shunting of plate loads by nonlinear cell/elements in equal measure is related also to tuned amplifiers.

Let us examine some special feature/peculiarities of the calculation of band-pass amplifiers from LAX.

The simplified circuit of cascade/stage with the two-circuit filter, shunted by nonlinear cell/elements, is depicted on Fig. as 81. The resistor/resistances R_1 and R_2 provide the required passband of cascade/stage during the amplification of low signals. By in principle nonlinear cell/elements can be shunted both one of the coupled circuits and both ducts. For the shunting of both ducts, it is necessary in n-cascade UPCh to apply the large amount of nonlinear cell/elements, that netselesoobrezno of one of the ducts.

Nonlinear cell/elements to include in the first (anode) duct inexpediently, that as in this case it is necessary to switch on the supplementary isolating capacitors, which prevent nonlinear cell/elements from high direct/constant andonoge voltage.

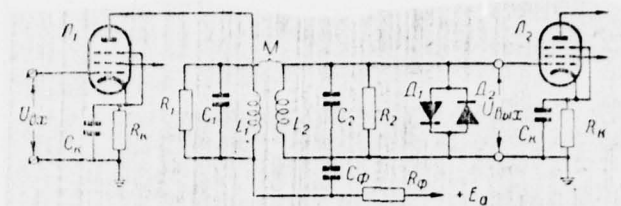
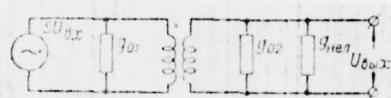


Fig. 81. The simplified circuit of cascade/stage with the two-circuit filter, shunted nonlinear elementai.

Fig. 82. Equivalent diagram of nonlinear cascade/stage with two-circuit filter.



In connection with this let us examine the logarithmic cascade/stage in which nonlinear cell/elements shunted the second (grid) duct.

Figure 82 depicts the equivalent diagram of nonlinear cascade/stage with dddvukhkorturnym filter, in which:

$g_{01} = g_{01x} + g_{0e1} + g_1$ is usudshennaya resonance conductivity of plate circuit; $g_{02} = g_{0e2} + g_{0x} + g_2$ - the impaired resonance conductivity of grid circuit not allowing for the conductivity of the nonlinear cell/element of g_{ne1} ; g_{0e1} and g_{0e2} is resonance conductivities of respectively anode and grid circuits.

one of the most essential deficiency/lacks in any logarithmic amplifier is the dependence of the zapazdyvaiya of signal at its output/yield and its passbands on the amplitude of input signal. If in cascade/stage with two-circuit filter changes resistor/resistance R_2 , which shunts the secondary circuit, then namen'sheye change in the time lag of signal it is reached with the relationship/ratio of the parameters

$$k_{c0} = \delta_1,$$

where

$\delta_1 = 1/\omega_0 C_1 R_{01}$ - the attenuation of the first duct;

$k_{c0} = \frac{M}{\sqrt{L_1 L_2}}$ - coupling coefficient;

M - the coefficient of vzaimoindktsii.

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Therefore it is most expedient to test of diagram and to find

expressions for the resistor/resistances of nonlinear cell/elements precisely for the case when $k_{CH} = \delta_1$.

For the diagram, depicted on Fig. 81, amplification factor of resonance in this case

$$K = \frac{\omega_0 S \sqrt{L_1 L_2}}{\delta_1 + \delta_2}, \quad (IV.1)$$

where

$$\delta_1 = \frac{\omega_0 L_1}{R_{01}} = \frac{R_{01}}{\omega_0 C_1}; \quad \delta_2 = \omega_0 L_2 g_2 = \frac{g_2}{\omega_0 C_2}; \quad g_2 = g_{02} + g_{\text{non}}. \quad (IV.2)$$

Under the condition of small voltages from 0 of up to the U_{ex} , when nonlinear cascade/stage works in linear conditions, is absent by-passing nonlinear cell/element, i.e., $g_{\text{non}} = 0$.

Then

$$g_2 = g_{02} = \frac{1}{R_{02}}; \quad \delta_2 = \frac{1}{\omega_0 C_2 R_{02}} = \delta_0$$

and

$$K_1 = \frac{\omega_0 S \sqrt{L_1 L_2}}{\delta_1 + \delta_0}. \quad (IV.3)$$

In the work of cascade/stage in logarithmic mode the output potential of the cascade/stage

$$U_{\text{exII}} = K_{II} U_{\text{exII}}.$$

Passing to the relative voltages z and x , we have

whence

$$\begin{aligned} z_{11} &= \frac{K_{11}}{K_1} x_{11}, \\ x_{11} &= \frac{K_1}{K_2} z_{11}. \end{aligned} \quad (\text{IV-4})$$

According to formulas (IV.1) and (IV.2) the relation

$$\frac{K_1}{K_{11}} = \frac{\delta_1 + \delta_3}{\delta_1 + \delta_0}. \quad (\text{IV-5})$$

Substituting in this otnoyeniye of the value of δ_1 , δ_3 and δ_0 , we obtain

$$\frac{K_1}{K_{11}} = \frac{R_{02}g_3 \left(\frac{1}{R_{02}g_3} + \frac{C_1 R_{01}}{C_2 R_{02}} \right)}{1 + \frac{C_1 R_{01}}{C_2 R_{02}}}. \quad (\text{IV-6})$$

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The degree of the communication/connection between ducts is characterized by the coefficient

$$\beta = \frac{k_{cb}}{\sqrt{\delta_1 \delta_3}}.$$

taking into account that in the case of $k_{cb} = \delta_1$, in question,

$$\beta = \sqrt{\frac{\delta_1}{\delta_3}}.$$

In the work of cascade/stage in linear conditions coupling

coefficient

$$\beta_0 = \sqrt{\frac{i_1}{i_0}} = \sqrt{\frac{C_2 R_{02}}{C_1 R_{01}}}. \quad (\text{IV-7})$$

After the substitution of expressions (IV.6) and (IV.7) into equation (IV.4) we obtain

$$x_{11} = z_{11} \frac{R_{02} g_2 \left(1 + \frac{\beta_0^2}{R_{02} g_2} \right)}{1 + \beta_0^2}. \quad (\text{IV-8})$$

According to expression (II.5) relative input voltage can be recorded in this form

$$x_{11} = e^{\frac{z_{11}-1}{a}}. \quad (\text{IV-9})$$

Equating the right sides of the expressions (IV.8) and (IV.9) and solving relative to g_2 , we find

$$g_{211} = \frac{e^{\frac{z_{11}-1}{a}} (1 + \beta_0^2) - \beta_0^2 z}{z R_{02}}, \quad (\text{IV-10})$$

whence

$$R_{\text{ref}11} = \frac{1}{g_{211} - g_{02}} = \frac{R_{02}}{\frac{e^{\frac{z_{11}-1}{a}} (1 + \beta_0^2) - \beta_0^2 z}{z_{11}} - 1}. \quad (\text{IV-11})$$

In the work of cascade/stage in quasi-linear mode/conditions, analogusly we have

$$x_{111} = \frac{K_1}{K_{111}} z_{111} = z_{111} \frac{R_{02} g_2 \left(1 + \frac{\beta_0^2}{R_{02} g_2} \right)}{1 + \beta_0^2}, \quad (\text{IV-12})$$

or according to expression (II.22)

$$x_{III} = \left(\frac{z_{III} - 1}{a} - \ln D_1 + 1 \right) D_1. \quad (IV-13)$$

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Equating the right sides of the expressions (IV-12) and (IV-13) and solving relative to g_{III} , we obtain

$$g_{III} = \frac{D_1 (z_{III} - a \ln D_1 - 1 + a) (1 + \beta_a^2) - \beta_a^2 z_{III}}{a R_{02} z_{III}}, \quad (IV-14)$$

whence

$$R_{II2,III} = \frac{R_{02}}{\frac{D_1 (z_{III} - a \ln D_1 - 1 + a) (1 + \beta_a^2) - \beta_a^2 z_{III}}{a z_{III}} - 1}. \quad (IV-15)$$

In the case of the shunting of grid circuit by 1st type nonlinear divider/denominator with by boll'shom the entry impedance of the following tube of the $(R_{ux} \rightarrow \infty)$ of vyrazhenaiya (IV-11) and (IV-15) it is necessary to multiply by $\left(1 + \frac{R_A}{R_{02}}\right)$.

Carried out by the author of investigation showed that the value of dianmicheskogo range and accuracy LAX in band-pass amplifier can be obtained approximately by the same as in resonance. However, band-pass amplifiers are more complex in adjustment than resonance, what is their deficiency/lack.

selective logarithmic amplifier with nonlinear current feedback.

The schematic diagrams of selective logarithmic amplifiers with nonlinear current feedback, intended for the amplification of vibrations up to 1 MHz frequency, differ from the diagram of symmetrical logarithmic video amplifier, depicted on Fig. 68, only by the fact that the plate loads of cascade/stages they are either single resonant circuits or two-circuit band-pass filter. During the amplification of vibrations with the frequencies, which reach dozens megahertz, pronounced by-passing stray capacitance on the cathode circuit of cascade/stage. Because of this the active nonlinear cell/element, shunted by stray capacitance, ceases to affect the factor of amplification of cascade/stage.

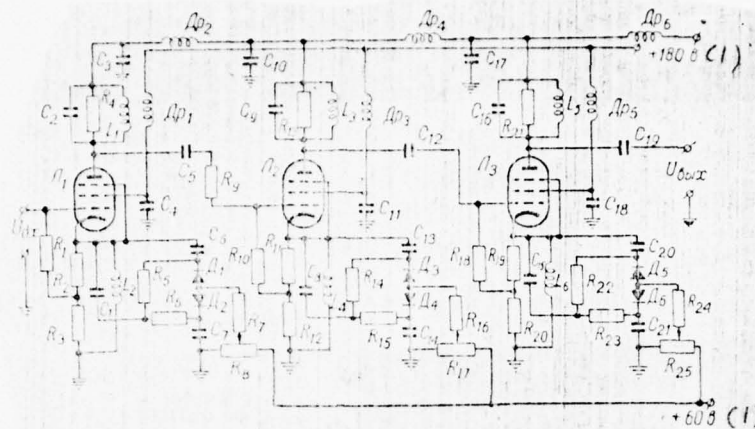


Fig. 83. Schematic diagram of resonance logarithmic amplifier with nonlinear current feedback: L_1, L_2, L_3 - 6J5P; R_1, R_{10}, R_{15} - 100 ccomas; R_3, R_{12}, R_{20} - 3.9 comas; R_2, R_{11}, R_{19} - 120 ohm; R_4, R_{13}, R_{21} - 3 comas; R_9 - 100 ohm; $R_5, R_6, R_7, R_8, R_{14}, R_{16}, R_{17}, R_{22}, R_{23}, R_{24}, R_{25}$ - 15 comas; C_1, C_8, C_{15} - 18 nf; C_2, C_9, C_{16} - 15 nf; C_5, C_{12}, C_{19} are 100 nf; $C_3, C_4, C_6, C_7, C_{10}, C_{11}, C_{13}, C_{14}, C_{17}, C_{18}, C_{20}, C_{21}$ is 0.01 μ F.

Thus, at high frequencies negative feedback they outstsvut.

For the elimination of this phenomenon into the cathode circuit of cascade/stage, it is necessary to include/connect the oscillatory circuit, tuned to a frequency of the amplified oscillations. During the calculation of cathode oscillatory circuit, one should consider that the value of stray capacitance between cathode and filament of tube for the different types of tubes varies within limits from 3 to 10 nf, but the capacitance value of mounting in cathode circuit can reach 10-15 nf. Figure 83 shows the schematic diagram of three-stage resonance logarithmic amplifier with nonlinear current feedback, while Fig. 84 - its experimental amplitude characteristic. Amplifier has the following parameters: resonance frequency $f_0 = 20$ MHz; the maximum factor of amplification $K_0 = 640$; passband of raboye amplifier in linear conditions $\Delta f = 1.2$ MHz. As nonlinear cell/elements are used the diodes of the type of the D2J to which from potentiometers R_8 , R_{17} and R_{25} are given the bias voltages of $E_{cm_{nen_1}} = E_{cm_{nen_2}} = 0,22$ V; $E_{cm_{nen_3}} = 0,23$ V.

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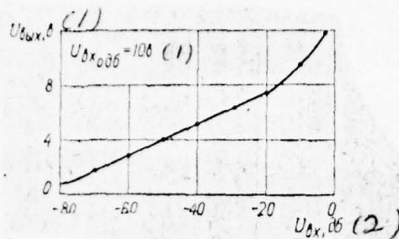


Fig. 84. Amplitude characteristic of tuned amplifier with nonlinear current feedback.

Key: (1). V. (2). dB.

Figure 84 shows that the range the LAX of amplifier is equal to $D = 56$ dB, which indicates the pocochednuyu work of nonlinear cascade/stages.

Accuracy LAX in selective amplifier with nonlinear feedback can be obtained order 1-20/o. Procedure for calculation of selective amplifier with nonlinear cell/elements in the cathode circuits of the cascade/stages of anaogichna to the procedure for calculation of logarithmic video amplifier. Difference entails the fact that in selective amplifier during the calculation of the resistor/resistance of feedback it is necessary to consider the resonance resistor/resistance of cathode circuit.

Logarithmic amplifier of radio pulses with gain control on pulse envelope.

Automatic gain control, in practice instantaneously, in the cascade/stage of the amplification of radio pulses can be obtained, utilizing negative feedback on pulse envelope. Let us examine the operating principle of the cascade/stage, simplified circuit of which is depicted on Fig. 85.

The resistor/resistance of R_K and the capacitance/capacity of C_K are selected so that the negative feedback on radio-frequency is absent, and on video frequency (on pulse envelope) it occurs, since in cathode circuit is isolated the detected video pulse. The rise time of video pulse in the cathode circuit of t_{yK} is considerably shorter

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than the pulse duration of t_H . In this case, must be fulfilled the inequality

$$t_{yK} \leq (0,1 - 0,2) t_H. \quad (IV.16)$$

The voltage of video pulse is the voltage, which automatically controls the amplification of cascade/stage during an increase in the signal.

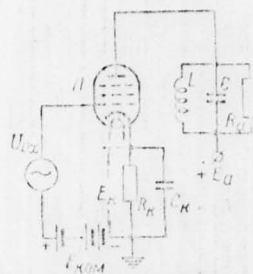


Fig. 85. The simplified circuit of cascade/stage with gain control on pulse envelope.

In order that the effect of detection of signal and control of the amplification of cascade/stage would begin with comparatively small input voltage and at the same time it was preserved the amplification of low signals, operating point necessary to select on the lower part of the linear section avoidno-grid the characteristic of tube. The effect of the gain control of cascade/stage grow/rises with uyelicheniyem the resistor/resistance of R_K , but in this case also increases the initial cathodic voltage of E_{K1} , which is isolated during the resistor/resistance of R_K with the course of the constant component of cathode current. For the establishment of operating point at the necessary position, it is necessary at great significance of R_K into the grid circuit of tube to include/connect the compensating positive voltage

$$\begin{aligned} E_{K0M} &= E_{K1} - E_{cmH} = \\ &= I_{K1} R_K - E_{cmH}, \quad (IV-17) \end{aligned}$$

where I_{K1} is a constant component of cathode current in the absence of signal; E_{cmH} - the initial bias voltage in the absence of signal.

Consequently, diagram works as follows. With small input voltage the constant component of cathode current virtually is not changed and amplification is not regulated. With an increase in the amplitude of input signal as a result of the nonlinearity of the characteristic of tube, grow/rises the constant component of cathode current, that leads to an increase in the bias voltage of E_{cm} and operating point 0 on plate characteristic during the action of momentum/impulse/pulse is shift/sheared to the left. In this case, the amplification of

cascade/stage decreases. It is possible to fit this value of the resistor/resistance of the R_k , with which is obtained the required for a successive work amplitude characteristic of cascade/stage. For obtaining effective AGC, it is necessary to apply the tubes, which have lvy characteristics with sharp as the cutoff of anode current, for example tube of the type of 6J1E, 6J3P, 6J5E, 6P9, 6P14P.

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The calculation of cascade/stage is reduced on the calculation of the curves of the dependence of a change in the constant component of the cathode current of the $I_{k, n} = f(U_{bx})$, of the bias voltage of $E_{cm} = \varphi(U_{bx})$ and fundamental harmonic of the anode current of $I_{a_1} = \theta(U_{bx})$ from the amplitude of the input voltage of U_{bx} for the different values of R_k and E_{cm} and the selection of the required curve $I_{a_1} = \theta(U_{bx})$ in the curves of $z = f(x)$ (see Fig. 13) for rated values x_1 and $K_1 = D_1$.

Curved $I_{k, n} = f(U_{bx})$ and $I_{a_1} = \theta(U_{bx})$ can be designed analytically, if are known the analytical expressions of the anodony and cathode characteristics of tube, graphically or to grafoanaiticheski, if there is a graphic representation of the characteristic of tube. The characteristics of tubes can be approksmirovany by different functions. The approximation of the characteristic of the tube of broken straight line for the calculation of amplifiers from LAX is unsuitable, since it gives large errors

especially for the tubes, imeyu'shchikh characteristics with the elongated lower bending.

Is widely common the image of the characteristic of tube with the aid of polynomial. Since the correct representation/transformation of real characteristic in wide range of change requires sufficiently the bol'shoyugo of the number of terms of polynomial, mathematical analysis is obtained comparatively bulkily.

Simplest and at the same time that giving high accuracy is the approximation of the characteristic of tube with the aid of hyperbolic tangent, proposed by professor N. N. Krylov,

$$i_a = I_{a_0} (1 + \tanh pq_a E_{cm}), \quad (IV-18)$$

where

$$q_a = \frac{S}{I_{a_0}};$$

I_{a_0} are an anode cathode current with of $E_{cm} = 0$; S - the mutual conductance of tube in rectilinear part; p is the coefficient with the aid of which it is possible to obtain the confrontation approximation of characteristic during a change in the stress over wide limits.

Approximation by the exponential function of $i_a = A(E_{cm} - E_{san})^n$ considerably simplifies mathematical analysis, if degree n integer (E_{san} - the cutoff voltage of tube).

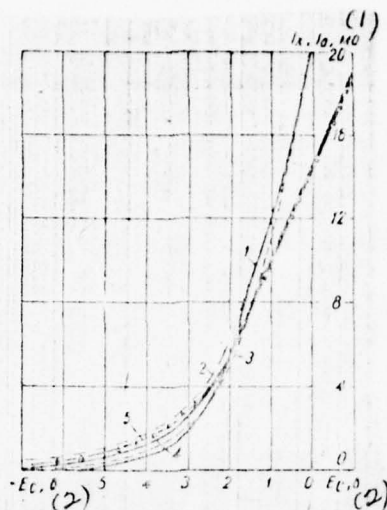


Fig. 86. Approximation of the cathode and plate characteristics of tubes 6J3P and of 6J1P by the hyperbolic tangent: 1 - 6J3P;

$$U_g = 200 \text{ V}; U_p = 150 \text{ V}; i_k = i_d + i_g = f(E_{cm}); \quad 2 - i_k = 20.1 \cdot 10^{-3}$$

$$(1 + \text{th } 0.42 E_{cm});$$

$$3 - i_k = 20.1 \cdot 10^{-3} (1 + \text{th } 0.493 E_{cm});$$

$$4 - 6J1P; U_d = U_g = 120 \text{ V};$$

$$i_d = f(E_{cm}); 5 - i_d = 14.8 \cdot 10^{-3} (1 + \text{th } 3.45 E_{cm}).$$

Key: (1) - mA. (2) - V.

Figure 86 shows the approximation of the cathode characteristic of a tube of the type of the 6J3P with of $U_2 = 200 \text{ V}$ and

$U_3 = 150 \text{ V}$ by hyperbolic tangent. with approximation is taken: the $I_{20} = 20.1 \text{ mA}$; $S = 8 \text{ mA/V}$; $p = 1.05$ (is curve 2) and $p = 1.23$ (is curve 3). Give of aporoksimatsiya sufficiently accurately reproduces the cathode characteristic of tube during a change in the stress of E_{cm} over wide limits.

For a circuit analysis, depicted on Fig. 85, we will use the approximation of the characteristics of tube by hyperbolic tangent.

During the supplying to the control electrode of the tube of alternating/variable sine voltage, the constant component of the cathode current of $I_{k.n}$ and the fundamental harmonic of the anode current of I_{21} can be determined sufficiently accurately by the method five ordinates [12]. The current of $I_{k.n}$ is determined from the formula

$$I_{k, n} = \frac{I_{\text{макс}} + I_{\text{мин}}}{6} + \frac{I_1 + I_2}{3}. \quad (\text{IV-19})$$

the procedure for the determination of the currents of

$I_{\text{макс}}$, $I_{\text{мин}}$, I_1 and I_2 is shown in Fig. 87. It is necessary to note that the current of $I_{k.n}$ must be designed from the cathode characteristic of the tube of $i_k = i_a + i_3 = f(E_{cm})$.

Since for the diagram, depicted on Fig. 85, bias voltage on the

control electrode of $E_{cm} = U_{bx} + E_{kom} - E_k$ with the
approximation of characteristic as hyperbolic tangent we have:

$$\begin{aligned} I_{HRC} &= I_{K0} [1 + \text{th } pq_K (U_{bx} + E_{kom} - E_k)]; \\ I_{MH} &= I_{K0} [1 + \text{th } pq_K (-U_{bx} + E_{kom} - E_k)]; \\ I_1 &= I_{K0} \left[1 + \text{th } pq_K \left(\frac{1}{2} U_{bx} + E_{kom} - E_k \right) \right]; \\ I_2 &= I_{K0} \left[1 + \text{th } pq_K \left(-\frac{1}{2} U_{bx} + E_{kom} - E_k \right) \right], \end{aligned}$$

where I_{K0} - a cathode current with the voltage of
 $E_{cm} = 0$; $q_K = \frac{S_K}{I_{K0}}$; S_K - the slope/transconductance of
the cathode characteristic of tube on straight portion.

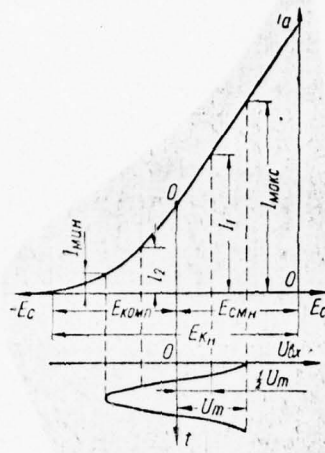


Fig. 87. Procedure for the determination of components from the method five ordinates with asymmetric characteristic.

Substituting the value of $I_{\text{макс}}, I_{\text{мин}}, I_1$ and I_2 into expression (IV-19), we obtain

$$I_{\text{к.п}} = I_{\text{к0}} \left\{ 1 + \frac{1}{6} [\text{th } pq_{\text{к}} (U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}}) + \text{th } pq_{\text{к}} (-U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}})] + \right. \\ \left. + \frac{1}{3} \left[\text{th } pq_{\text{к}} \left(\frac{1}{2} U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}} \right) + \text{th } pq_{\text{к}} \left(-\frac{1}{2} U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}} \right) \right] \right\}. \quad (\text{IV-20})$$

In turn,

$$E_{\text{к}} = I_{\text{к.п}} R_{\text{к}}. \quad (\text{IV-21})$$

This equation is transcendental and can be solved graphically.

If alternating voltage on control electrode is equal to zero, i.e., $U_{\text{вх}} = 0$, then the constant component of the cathode current

$$I_{\text{к.п}} = I_{\text{к0}} [1 - \text{th } pq_{\text{к}} (E_{\text{к}} - E_{\text{ком}})]. \quad (\text{IV-22})$$

For the calculation of the amplitude characteristic of cascade/stage, it is necessary to find the amplitude of the fundamental harmonic of anode current which according to [12] is equal to

$$I_{a1} = \frac{1}{3} (I_{\text{макс}} - I_{\text{мин}} + I_1 - I_2), \quad (\text{IV-23})$$

or

$$I_{a1} = \frac{I_{a0}}{3} \left[\text{th } pq_a (U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}}) + \text{th } pq_a (U_{\text{вх}} - E_{\text{ком}} + E_{\text{к}}) + \text{th } pq_a \left(\frac{1}{2} U_{\text{вх}} + E_{\text{ком}} - E_{\text{к}} \right) + \right. \\ \left. + \text{th } pq_a \left(\frac{1}{2} U_{\text{вх}} - E_{\text{ком}} + E_{\text{к}} \right) \right]. \quad (\text{IV-24})$$

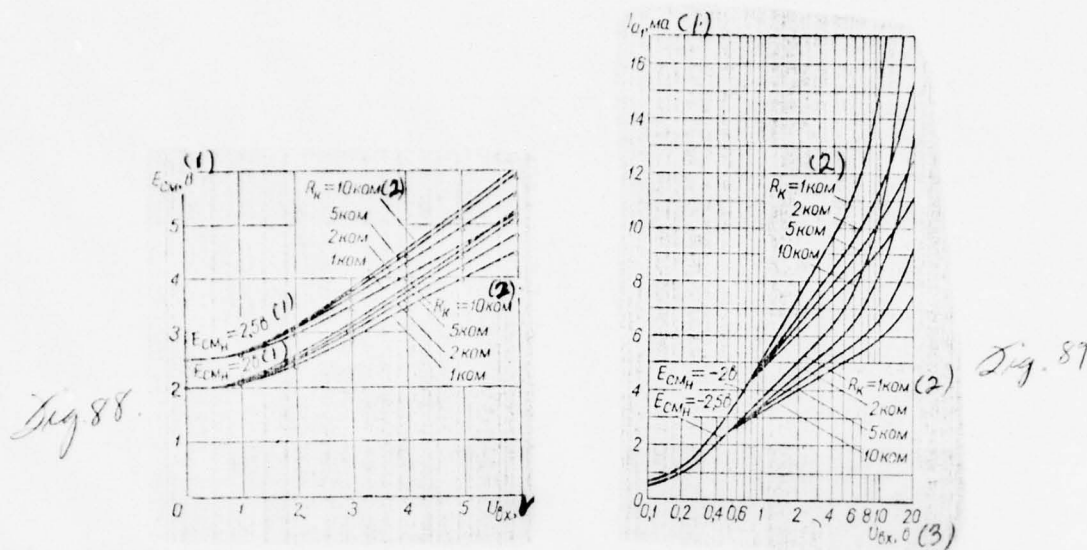


Fig. 88. Curved changes in the bias voltage depending on the amplitude of input voltage for the tube of the 6J3P with of

$U_a = 220 \text{ V}$ and an $U_g = 150 \text{ V}$.

Key: (1). V. (2). comas.

Fig. 89. Curved changes of the fundamental harmonic of the anode cathode current of 6J3P depending on input voltage.

Key: (1). mA. (2). comas. (3). V.

In this case, output potential of cascade/stage on the radio-frequency

$$U_{\text{Bld},p} = I_{a1} R_0, \quad (\text{IV-25})$$

where R_0 is the total resistance of the plate load of cascade/stage.

Figure 88 depicts calculated curve $E_{\text{CM}} = \varphi(U_{a2})$ for the tube of 6J3P at two values of the initial displacement of $E_{\text{CMH}} = -2$ and -2.5 V the different values of the resistor/resistance of R_K , in the same figure are shown the experimental points, which coincide sufficiently well with calculated which indicates the high accuracy of the method five ordinates.

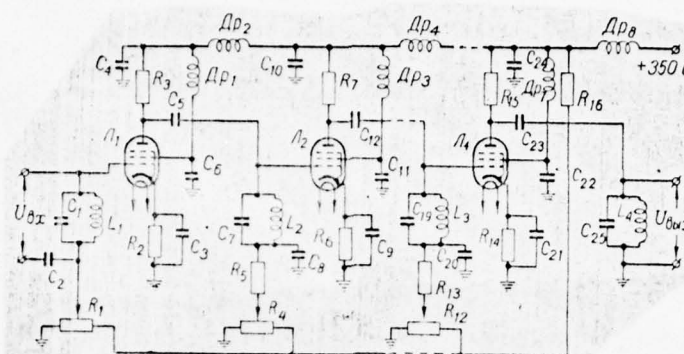


Fig. 90. Schematic diagram of resonance logarithmic amplifier on pulse envelope: L_1, L_2, L_3, L_4 - 6J3P; R_1, R_4, R_{12} - 100 kom; R_2, R_6, R_{14} - 2 comas; R_3, R_7, R_{15} - 2.7 comas; R_5, R_{13} - 33 comas; R_{16} - 300 comas; $C_1 = 24$ nf; C_7, C_{19} - 18 nf; C_{25} - 24 nf; C_3, C_9, C_{21} - 240 nf; $C_2, C_4, C_6, C_8, C_{10}, C_{11}, C_{20}, C_{22}, C_{24}$ - 910 nf; C_5, C_{12}, C_{23} are 100 nf.

Figure 89 depicts the calculated curves of the dependences of fundamental harmonic of anode current on the input voltage of

$I_{a1} = \theta(U_{BX})$ at the same values of the voltage of E_{cmH} and resistor/resistance of R_K .

Comparing Fig. 89 with Fig. 13, we see that calculated curve $I_{a1} = \theta(U_{BX})$ in their character coincide sufficiently well with the curves of $z = f(x)$. This it indicates the possibility of the realization of the successive work of cascade/stages and obtaining precise by the LAX of multistage amplifier over a wide range.

Being given the different value of the resistor/resistance of plate load, from the curves of $I_{a1} = \theta(U_{BX})$ they design several families of the amplitude characteristics of cascade/stage. From these families it is necessary to select that characteristic which satisfies the successive work of cascade/stages.

This characteristic is the curve, depicted on Fig. 89, during the initial bias voltage of $E_{cmH} = -2,5 \text{ V}$, the resistor/resistance of the $R_K = 2 \text{ cmas}$ and the total resistance of plate load $R_0 = 2 \text{ cmas}$.

Figure 90 shows the schematic diagram of the four-stage amplifier (without the third cascade/stage), assembled on the basis of the calculations conducted.

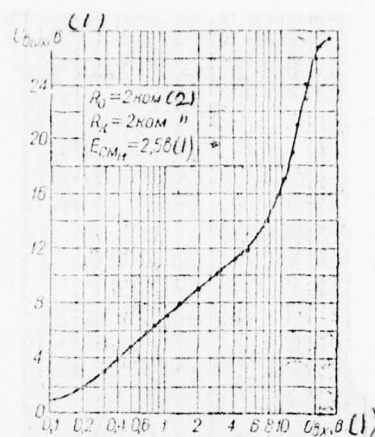
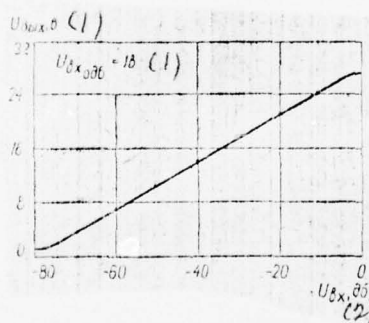


Fig. 91. Amplitude *kharakkteristika* of cascade/stage with gain control on otibayushchey radio pulse.

Key: (1). V. (2). comas.

Fig. 92. Amplitude characteristic of four-stage amplifier with gain control on otibayushchey radio pulse.

Key: (1). V. (2). dB.



In work in linear conditions, the amplifier has the following parameters: resonance frequency $f_0 = 30$ MHz; common/general/total factor of amplification $K_0 = 10^4$ (neg) passband $\Delta F = 1$ MHz; the factor of amplification of one cascade/stage $K_1 = 10$. four tubes of the type of 6J3P, utilized in amplifier, are fitted on the uniformity of the parameters of 20 pcs. Tubes were take/selected on the current of I_a , with the bias voltage of $E_{cm} = 0$ and to the cutoff voltage of the tube of E_{cut} . The scatter of the parameters was allow/assumed not more than 50/o. The which compensate for voltages for a convenience the sediment of the LAX of amplifier are remove/taken from the separate potentiometers R_1, R_4, \dots, R_{12} .

Figure 91 shows design characteristics and experimental points of the characteristic of the third cascade/stage. Characteristic was remove/taken with connected that which follow, i.e., the fourth, cascade/stage. Experimental characteristic coincides sufficiently well with calculated and satisfies the requirements for the successive work of cascade/stages.

Figure 92 gives the experimental amplitude characteristic of four-stage amplifier. Dynamic range LAX D - 70 dB instead of those which are expected 80 dB. Range LAX was the less expected because of overloading last/latter cascade/stage. Accuracy LAX in all range is not worse than 2-40/o.

With capacitance/capacities in the cathode circuits of amplifier stages (C_3, C_9, \dots, C_{21}) $C = 200-500$ nf time of gain control by amplifier does not exceed the tenths of microsecond.

The diagram of logarithmic amplifier with gain control on pulse envelope has the following advantages: 1). the sufficiently high stability of the parameters of amplifier, which is provided by negative feedback (OOS) on direct current and by the absence of nonlinear semiconductors; 2). short time of gain control, which does not exceed the tenths of microsecond; 3). the small overall sizes of amplifier, equal to the overall sizes of usual selective amplifier.

Deficiency/lacks in the diagram are the criticality LAX to the exchange of tubes and the need for application/use in amplifiers with the dynamic range of LAX more than 60 dB of tubes with lvymi anode-grid characteristics.

§2. Obtaining LAX in selective amplifiers by the addition of the voltages from the output/yields of cascade/stages.

The method of obtaining LAX in selective amplifiers by the addition of the voltages from the vyukhodov of cascade/stages is known in the literature [34] as method of consecutive detektiravaniya. This method most frequently is applied for obtaining LAX in the amplifiers of radio pulses. There are several circuit solutions of the method of consecutive detection. the essence of the work of all

diagrams is identical and minutely examined in §2 chapter II.

usually amplifier consists of several amplifier stages, from output/yields of which the detected voltages pctupayut for overall load. To amplify and to detect the voltage of high frequency they can one or two separate electronic devices. Depending on that, how many instruments amplify and detect, the diagrams of consecutive detection it is possible to divide into diagrams with separate detectors; by anode rectification; by cathode detection; by grid detection.

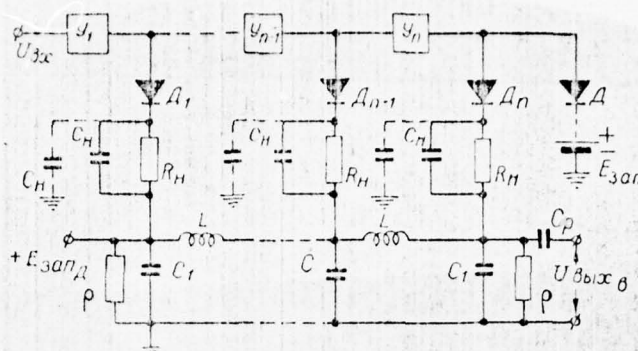


Fig. 93. The simplified circuit of selective logarithmic amplifier with separate detectors.

Selective logarifmicheskiy amplifier with separate detectors.

In the simplified circuit of selective logarithmic amplifier with separate detectors (Fig. 93) the voltage of high frequency is amplified by cascade/stages Y_1, Y_{n-1}, Y_n to output/yields of which are connected detectors D_1, \dots, D_{n-1}, D_n , which have both the particular loads of R_n and the boshchuyu $R_n = \frac{P}{2}$, on which store/add up themselves prodetktirovannye of napryazhenie. In this diagram each tube works as amplifier or as output stage. With small input voltage the cascade/stages have linear amplification, then with an increase of tension, amplification decreases and finally cascade/stage is impregnated. Since with an increase in the signal all cascade/stages, beginning with the latter, consecutively are overloaded, very important in order that the behavior of cascade/stage in the handled sosotyaniy would be completely determined. It is necessary also in order that output potential of cascade/stage during saturation would be constant and it did not depend on the value of signal (Fig. 94a).

For an amplifier stage in work with overloading, it is necessary thoroughly to select diagram and tube. All amplifier stages must be identical not only in the relation to the used in them tubes, but also the operating conditions, how this are allowed tolerances to network elements.

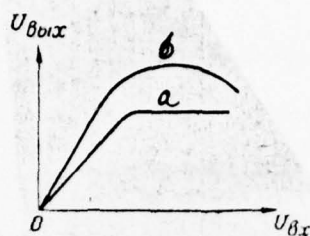


Fig. 94. Amplitude characteristics of cascade/stage with the overloading: a). good; b). poor.

The values of the input and output voltages with which begins the saturation of amplifier stage, depend on several factors, for example on the slope/transconductance of the dynamic characteristic of tube, effect of the grid cathode currents of datum and following cascade/stages. The effect of grid cathode currents is equal for all cascade/stages, except the latter. In order that the level of the saturation of the last/latter cascade/stage on the output voltage would not be above than in remaining cascade/stages, its output/yield must be shunted by the semiconductor diode, limiting output voltage (Fig. 93).

It is necessary to note that during the saturation of cascade/stage the current of screen grid noticeably increases which leads to a decrease in tension on the screen grid of tube. A decrease in this voltage causes a sharp decrease in the anode current and, consequently, also output voltage, what is inadmissible (Fig. 94b).

For toyugo in order to attain the constancy of the output voltage of cascade/stage in saturation mode, it is necessary to ensure the constancy of voltage on the screen grid of tube. This it is possible to achieve by the following methods: 1). by the selection of the largest possible value of the capacitance/capacity of the C_s , which shunts screen grid. During the amplification of pulse signals, postoyanaya time of the capacitance/capacity of C_s and anode resistance on screen grid during overloading must be larger in comparison with the repetition period of momentum/impulse/pulses. In this case the voltage on screen grid remains virtually constant. The

limiting factor are the overall sizes of condenser/capacitor; 2). by application of voltage on the screen grid of tube from voltage divider R_3 and R_4 on Fig. 57). The values of the resistor/resistances of divider/denominator are selected by such that the current of divider/denominator would be 10 times more than the current of screen grid. In this case, the capacitance/capacity of C_2 it is possible to undertake somewhat lesser than in the first case; 3). by application of voltage on screen grid it is direct from of the anode power supply through the throttle/choke. In this case the capacitance/capacity of C_2 can be selected smallest from all three examined cases. The constancy of voltage on screen grid is provided by the constancy of the voltage of anode power supply.

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During consecutive detection the cascade/stages of logarithmic amplifier are not protected from overloading, but signal is remove/taken from the output/yields neperegruzhennykh cascade/stages. Virtually this system of gain control is low-inertia. For the rapid restoration/reduction of the maximum sensitivity of amplifier after the action of large signals, it is necessary that the handled cascade/stages fast enough would restore their maximum sensitivity. For this purpose, it is necessary to provide a series of measures, and detail to ensure the virtually instantaneous discharge of the transient capacitance/capacity of C_2 after the break-down of large signal. The sufficiently rapid discharge of the capacitance/capacity

of C_e charged by the grid currents of the handled tube, it is possible to obtain, after selecting the diagram of amplifier stage with parallel feed and after include/connecting into the circuit of the control electrode of tube throttle/choke instead of the high the effective resistance of escape, if amplifier stage is assembled by diagram with series feed.

The time constant of cathode circuit (circuit of automatic displacement) must be selected greater in comparison with the amplified frequency and lesser in comparison with the duration of pulse signal. In this case, the recovery time of cathode circuit will be small.

For a cascade/stage with kolbatel'nym duct in grid circuit with the correctly selected time constants of decoupling filters and cathode circuit recovery time after overloading can be obtained the $t_0 = (1-2) \times 10^{-7} \text{ s}$. Consequently, in the amplifier, which consists of the correctly designed amplifier stages, gain control and the restoration/reduction of the maximum sensitivity after the action of large signals will occur fast enough.

The detected output voltages from several amplifier stages will be feed/conducted to the overall load on which they store/add up themselves. the addition of the detected voltages must be linear, the otherwise amplitude characteristic of amplifier will differ from the logarithmic.

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The fronts of the video pulses, which entered from the output/yields of detectors, must coincide in time on overall load, otherwise the rise time of output pulse will sharply decrease in accordance with an increase in the signal. For the coincidence of the fronts of video pulses, it is necessary to utilize the artificial lines which must 'zaderrzhivat' video pulses from different detectors to time intervals, in the first approximation, the equal to transit time of the signal through the resonance amplifier stage. The transit time of the signal through the amplifier stage (delay time in the cascade/stage) it is possible with a sufficient degree of accuracy according to [34] to determine by the formula

$$t_{3,K} = \frac{1}{\pi \Delta F_1}, \quad (IV-26)$$

where ΔF_1 is a passband of cascade/stage.

With the overloading of cascade/stage, appear the grid currents, which decrease the input impedance of a tube, which leads to a decrease in the value of the load of the preceding/previous cascade/stage and, consequently, also to the delay time in the cascade/stage of $t_{3,K}$. In formula (IV-26) is not taken into account the effect of the grid currents of the subsequent tube for a period of $t_{3,K}$.

In the logarithmic selective amplifier of the ispol'zuyu'sya of delay line both in the concentrated and distributed parameters. In this case, the delay lines must satisfy the following requirements: the delay time in the cut of line, connected between two amplifier stages, in the first approximation, must be equal to the transit time of momentum/impulse/pulse through the amplifier stage. When at the output of amplifier is required strict constancy of the pulse rise-time during a change in the input signal in all dynamic range, the time of the cut of line must be completely determined: delay lines must have sufficiently wide passband in order that would not be distorted the video pulses, passing through the delay line. The wider the passband of line, the lesser the rise time and iskazhdeniya of video pulse at the output/yield of line; delay lines must to have high quality in order not to introduce high attenuations.

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The detailed theory of artificial lines delays (filters) both in those which were concentrated and in the distributed parameters, and also the procedure for calculation of these lines are presented in the literature [19], [20]. In the present work are examined the only some positions about delay lines, necessary for the design of amplifiers from LAX. As shown in work [20], line the delays in the concentrated constants can consist of T- and P- figurative component/links of the type constant k or derived component/links of the type "m". In the simplified amplifier circuit, depicted on Fig. 93, is applied the

delay line sososredotochennymi parameters, that consists of L-shaped component/links of the type "k". The delay time in the component/link of the type "k" according to [20] is determined from the formula

$$t_3 = \sqrt{LC}, \quad (IV-27)$$

where L - the series inductance of component/link; C is the shunt capacitance of component/link.

If delay line consists of n of component/links, then caused by time base of the delay

$$T_3 = nt_3, \quad (IV-28)$$

If between amplifier stages it is included on one component/link, then must be fulfilled the raventsvo

$$t_3 = t_{3, \kappa} \quad (IV-29)$$

or

$$\frac{1}{\pi \Delta F_1} = \sqrt{LC}. \quad (IV-29a)$$

Any section of delay line which connects the detectors of adjacent cascade/stages. it is at the same time the interstage filter, which does not pass intermediate frequency in order that in delay line would not appear reflections, it must be loaded from output/yield and input by the effective resistance, equal to its characteristic (wave) resistor/resistance

$$Z \cong Z_{\text{out}0} = \rho = \sqrt{\frac{L}{C}}, \quad (IV-30)$$

where ω - angular frequency.

It should be noted that the delay time in the τ_3 and line characteristic depend on frequency. In this case, virtually it is not possible to match line with load in the broad band of the propuskaiya of frequencies.

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Work [42] shows that only for one section of the type "k" are found the optimum values of load for the case when load consists of effective resistance R , which do not depend on frequency. In this case, is reached the constancy only of one of the parameters of delay line in broadband.

Thus, for instance in order to obtain for a T-component/link active line impedance, one should select $R = 0.75\rho$; in order to obtain the minimum of jet/reactive impedance - $R = 0.95\rho$, and the constancy of delay time - $R = 0.97\rho$. For a p-component/link the values of these coefficients are respectively equal to 1.5; 2.06; 1.65.

As a result of a change in the characteristic impedance the agreement of delay line in load can be ensured virtually only in part of the band of transparency. For component/links of the type "k" the characteristic impedance approximately is constant within the limits approximately of the half of the band of transparency. Therefore

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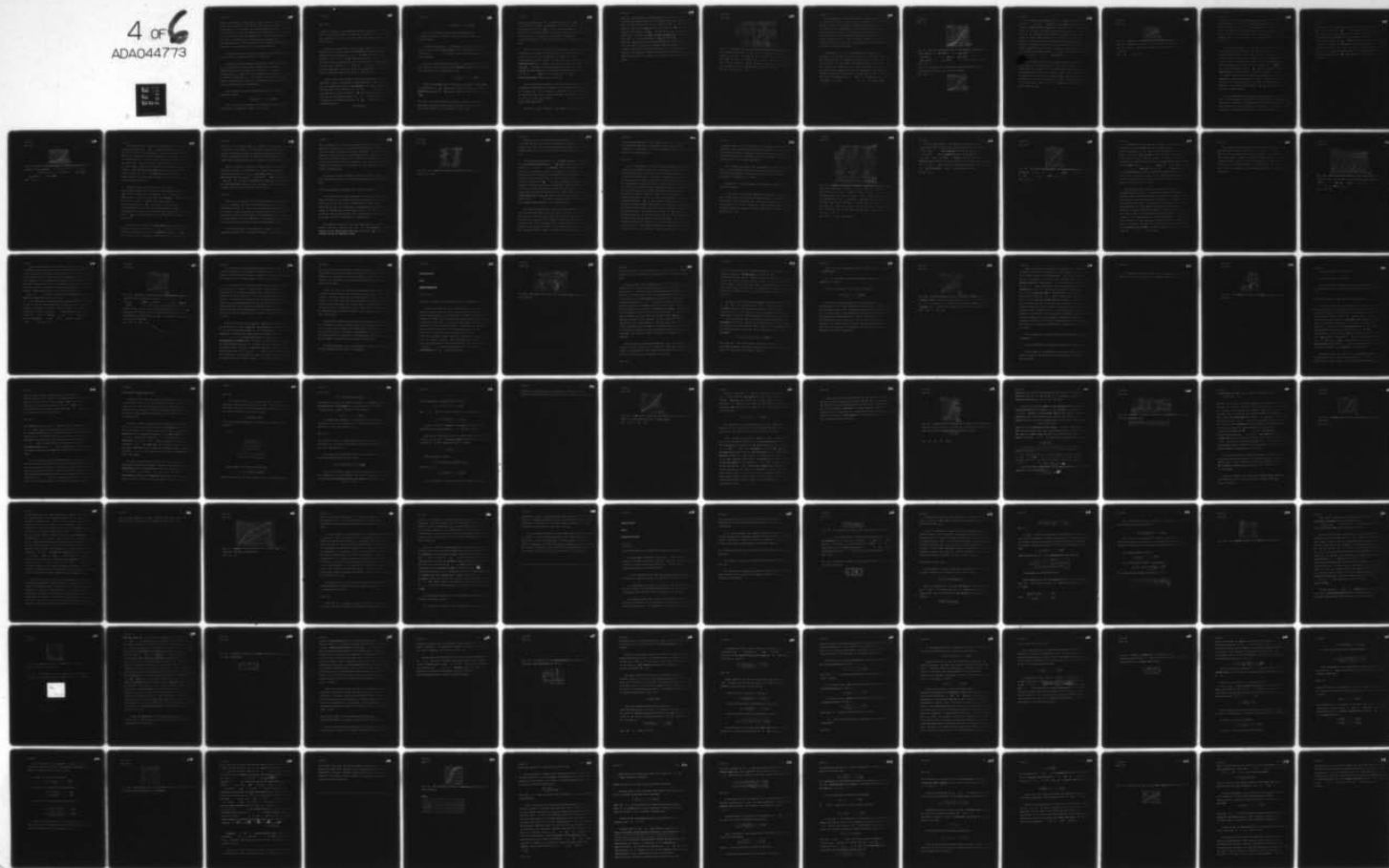
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during calculations of delay lines, which consist of component/links of the type constant k , even when are not presented stringent requirements for the fidelity of momentum/impulse/pulses, tentatively it is possible to count the passband of frequencies not of the cl'sh of the half of the band of transparency. The poor ispol'zovaiye of the band of transparency in the delay lines, comprised of component/links of the type constant k , is essential deficiency/lack and limits the possibilities of their application/use.

Considerably better is utilized the band of transparency, if are applied derived component/links of the type "m".

By applying derived component/links of the type "m", possible:

1). to expand the frequency band, within limits of which osushchestvletsya the agreement with load; 2). to expand the frequency band, in limits of which sufficiently accurately is retained the value of delay time; 3). to increase the delay time, caused by separate component/link, with the preservation/retention/maintaining of the pulse rise-time at output/yield.

Delay time in the derived component/link of the type "m" according to [20]

$$t'_3 = m\sqrt{LC}. \quad (IV-31)$$

value m at which is provided the constancy of delay time in possibly more broadband, is equal to 1.23 [20].

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A further decrease in the frequency and phase distortions in delay lines is possible by means of connection in parallel to the inductive line elements of a delay in special corrective capacitance/capacities [19] and [42].

The very good parameters possess delay lines in the distributed parameters, the carried out in very broad band transparency (with the maximum cut-off frequency of F_{MARC} to 10-20 MHz) and in high quality. Such lines it is most expedient to apply in UPCh, intended for amplification narrow pulses with the duration of $t_n \leq 0.5 \mu\text{s}$. For the pulse durations of $t_n \geq 0.5 \mu\text{s}$, when it is required to obtain considerable delay time between cascade/stages, these lines they are obtained sufficiently large in overall sizes.

When on both dead endings of delay are included the effective resistance, equal in magnitude to wave impedance ρ delay line (Fig. 93), the common/general/total load impedance on video frequency for all detectors of the amplifier of $R_{\text{n.o.}} = 0.5 \rho$. The value of the load impedance of each detector of R_H is selected several times more than the resistor/resistance of $R_{\text{n.o.}}$. In work [34] is recommended the resistor/resistance of R_n to select from the relationship/ratio

$$R_n = (5 \div 10) R_{\text{n.o.}}$$

or

$$R_n = (3 \div 5) \rho. \quad (IV-32)$$

This is necessary in order that comparatively low resistor/resistances ρ would not shunt the plate circuits of cascade/stages.

Capacitance values of C_n shunting the load of detector, and also the value of the time constant of the load circuit of the detector of $\tau_n = C_n R_n$ design just as for the detector of usual pulse receiver.

When the resistor/resistances of R_n are present, the detected video voltage from the load of each detector transmits to overall load only partially with transmission factor

$$k_p = \frac{\rho}{2R_n + \rho}. \quad (IV-33)$$

During satisfaction of the condition (IV-32) of $k_p = 0.15 - 0.25$. The coefficient of k_p can be made equal to unity, if we exclude the resistor/resistances of R_n and to leave the only overall load of $R_{H.0}$.

Page 143. But since resistor/resistance ρ even in narrow-band amplifiers virtually cannot exceed the value of 3-5 comas as a result of the difficulty of the production of delay line,

exception/elimination of the resistor/resistances of R_H will lead to the powerful shunting of amplifier stages are small, by the resistor/resistance of $R_{H.c}$. This deficiency/lack can be removed, by supplying to soptorivleniye ρ the voltage of $E_{\text{зап.д.}}$ locking detectors. In this case, it is possible to umen'isht' the value of resistor/resistance ρ , which will facilitate the execution of delay line.

Figure 95 depicts the schematic diagram of six-stage logarithmic amplifier with separate detectors (since all cascade/stages are uniform, for the sake of simplicity in diagram 3, 4 and 5 cascade/stages are not shown). As detectors (D_1, D_2 etc.) are used germanium diodes of the type of D2J with the particular loads of the $R_H = 6.8$ of comas (resistor/resistance R_3, R_8, \dots, R_{23}). Cover by load for each detector it is sum the resistor/resistance of $R_H = R_H + \frac{\rho}{2}$, equal to 9.25 comas ($\rho = 4.7$ comas - resistor/resistance R_5 and R_{24} in Fig. 95).

The operating mode amplifier stages is selected with respect to experimental characteristics osglasno to the requirements, indicated in §2 chapter II. Let us examine the prcedure for the selection of the operating mode stages of amplifier (Fig. 95) for tubes of the type of 6J3P (($U_a = 200$ V; $E_{cm} = 1.25$ V) and of the 6K4P ($U_a = 150$ V; $E_{cm} = -1$ V).

Figure 96 on semilogarithmic scale depicts the calculated linear

amplitude characteristic of cascade/stage (is curve 7) and the experimental characteristics of the cascade/stages, assembled on the tubes of 6J3P (curves 1, 2, 3) and of 6K4P (curves 4, 5 6), for the different values of voltage on the screen grid of U_3 and with fixed rovanom bias voltage of E_{cm} . cascade/stages have sledyushchiye parameters: resonance frequency 16 MHz, passband $\Delta F_1 = 1.8$ MHz, the delay time in the cascade/stage of $t_{3,k} = 1.77 \cdot 10^{-7}$ s. The amplitude characteristics of cascade/stages are removed for the real case upon their inclusion into common amplifier circuit. In each case of taking amplitude terminal characteristic of cascade/stage, were connected the analogous cascade/stage with that operating mode and the detector, assembled on a diode of the type of D2J with the load of 9.2 comas.

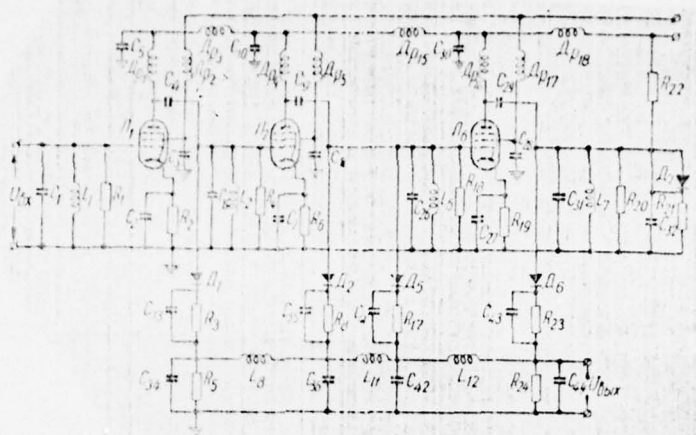


Fig. 95. Schematic diagram of resonance logarithmic amplifier with the separate detectors: L_1, L_2, \dots, L_6 - 6J3P; R_1, R_4, R_8 - 2.4 comas; R_2, R_6, R_{19} - 120 ohm; $D_1, D_2, \dots, D_5, D_6$ - D2J; R_3, R_8, R_{23} - 6.8 comas; R_5, R_{24} - 4.7 comas; C_{36}, \dots, C_{42} - 39 nf; C_4, C_9, \dots, C_{29} - 150 nf; C_{34}, C_{44} - 20 nf; $C_2, C_3, C_5, C_{10}, C_7, C_8, C_{27}, C_{30}, C_{28}$ are 10 thous. nf; C_{32} - 5600 nf; L_8, L_{11}, L_{12} - 800 μ H; C_1 - 39 nf; C_6, C_{26} - 33 nf; C_{21} - 35 nf.

The experimental characteristics of cascade/stages as a result of the shunting of plate load by the input admittances of the following tube and detector considerably differ from the linear and have sufficiently large logarithmic section (direct/straight section of characteristic). Thus, for instance, for the tube of 6J3P characteristic 2 has logarithmic section during a change in the input voltage from 0.3 to 2 in. With a further increase in the input voltage, begins the saturation of cascade/stage and output voltage it sotaetsya by virtually constant.

Characteristic 2 in the greatest measure satisfies the requirement for obtaining precise by the LAX of n-cascade amplifier. This characteristic is separately depicted on Fig. 97 (is curve 1). In this figure are also shown the characteristics of cascade/stage the video voltage as a function of the input radio-voltage: experimental (is curve 2) and required (is curve 3), calculated from formulas (II-47), (II-49) and (II-51) with consideration the real transmission factor of the detector of k_d . Curve is designed for the case:

$$U_{BX1} = 0.3 \text{ V}; \quad U_{BX2} = 3 \text{ V};$$

$$D_1 = K_1 = 10; \quad K_1 U_{BX1} R_A = 2 \text{ V};$$

$$a = 1.$$

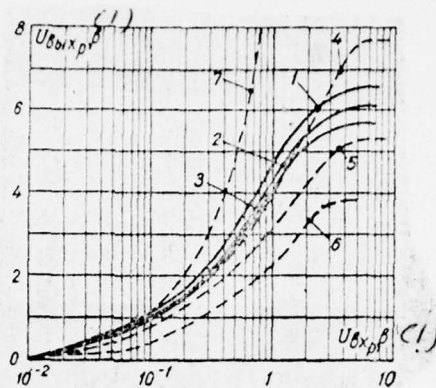


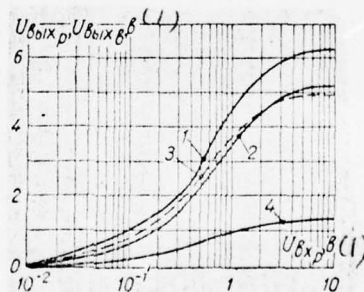
Fig. 96. Amplitude characteristics of the resonance cascade/stage:

— δ_{zhEP} ; 1 - $U_3 = 150 \text{ V}$ 2 - $U_3 = 125 \text{ V}$; 3 -
 $U_3 = 100 \text{ V}$; - - - - - 6K4P ; 4 - $U_3 = 100 \text{ V}$; 5 -
 $U_3 = 75 \text{ V}$; 6 - $U_3 = 50 \text{ V}$; 7 - linear characteristic.

Key: (1). V.

Fig. 97. Calculated and experimental amplitude characteristics of cascade/stage on radio- and to video voltage.

Key: (1). V.



The values of the coefficient of k_A were determined from the curve of $k_A = f(U_{bx_A})$, that which was removed experimentally. Figure 97 shows that the experimental characteristic of cascade/stage (curve 2) coincides sufficiently well with that which is required (is curve 3). It somewhat differs from the required characteristic to lesser side with small voltages and to large side - with high voltages. These divergences must mutually compensate for in multistage amplifier, since they have different signs. Figure 97 also depicts amplitude characteristic on video voltage taking into account the transmission factor of the k_p , which in this case accordingly (IV-33) is equal $k_p = 0,25$ (is curve 4).

For the tube of 6K4P in the greatest measure, satisfies the requirement for obtaining precise by the LAX of amplifier characteristic 5 on Fig. 96. In sootvetstviu with the examined recommendations regarding the diagram, shown in Fig. 95, are designed two amplifier on the tubes of 6J3P and 6K4P. The cascade/stages, assembled on the tubes of 6J3P, have a factor of amplification $K_1 = 10$, on the tubes of 6K4P - $K_1 = 8$. Passband of both amplifiers of order 0.55-0.57 MHz.

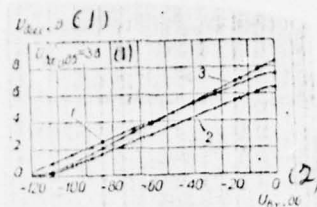


Fig. 98. Amplitude characteristics of resonance logarithmic amplifier with the separate detectors: 1 - on the tubes of 6J3P; 2 - on the tubes of 6K4P; 3 - during the supplying of cutoff voltages on detectors.

Key: (1). V. (2). dB.

Delay line is made from L-shaped component/links of the type "K" with wave impedance $\rho = 4.7$ ohms. Capacitance/capacity of the component/link of line $C = 39$ pF, inductance $L = 800$ μ H. Figure 98 gives the experimental characteristics of both amplifiers. Accuracy LAX is obtained not worse than 2-4% for the first amplifier in dynamic range to 100 dB and for the second amplifier - in the range to 85-90 dB.

During wave impedance $\rho = 4.7$ ohms the design of delay line is hindered/hampered as a result of the large inductance of the component/link of line. This delay line has considerable overall sizes, insertion losses and the distortions of momentum/impulse/pulse. If we decrease the resistor/resistance ρ , after leaving by the constant/invariable of the resistor/resistance of R_H (Fig. 93), then the transmission factor of k_p sharply decreases and the LAX of amplifier will go more hollow. In order to preserve the value of k_p with a decrease in the resistor/resistance ρ , it is necessary to decrease the resistor/resistances of R_H , which will lead to an increase in the shunting of the plate load of cascade/stage and a decrease in its amplification factor. The LAX of amplifier in this case will go more hollow.

In each concrete/specific/actual case during the project of delay line, it is necessary to proceed from the permissible distortions of video pulse, obtaining the sufficiently large coefficient of k_p and good filtration of high frequency in delay line. For obtaining good filtration, the capacitance/capacity of the component/link of delay

line must be the sufficiently large that it leads to a decrease in ρ and coefficient of K_p . This otivorechiye especially develops itself during the amplification of frequencies below 15-20 MHz. For the exception/eliminations of this contradiction of the capacitance/capacity of C_H which block the resistor/resistances of R_H , it is possible to include by the second end/lead not to delay line, but directly to the earth, as this is shown by primes in Fig. 93. The best result is obtained with the exception/elimination of the resistor/resistances of R_H and supply to the detectors of cutoff voltages.

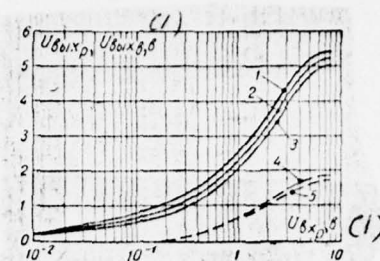


Fig. 99. Amplitude characteristics of cascade/stage with cutoff voltages on the detector: 1, 4. $-E_{\text{запд}} = 0.5 \text{ V}$; 2 -

$E_{\text{запд}} = 0.3 \text{ V}$; 3, 5.

$E_{\text{запд}} = 0.1 \text{ V}$

Tube 6J3P;

$U_a = 120 \text{ V}$; $U_b = 150 \text{ V}$.

Key: (1). V.

The possibility of designing of logarithmic amplifier without the resistor/resistances of R_H (resistor/resistance R_3, R_8, \dots in Fig. 95) is checked experimentally. In order to improve filtration between cascade/stages in high frequency, the capacitance/capacity of the component/link of delay line was increased 9 times, and line characteristic - selected as being equal to 600 ohm. In this case, the $R_{H,0} = 300$ ohm, and the inductance of component/link decreased 9 times. Figure 99 for the present instance and for the different cutoff voltages of $E_{\text{сигн}}$ on detector depicts amplitude characteristics on radio-voltage (curves 1, 2 and 3) and on video voltage (curves 4 and 5).

Comparing figures 96, 97 and 99, we see that with exception/elimination of the diagram of the resistor/resistances of R_H and the application of voltage of $E_{\text{сигн}}$ the amplitude characteristic on radio-voltage with large signals is arranged below, but on video voltage - somewhat higher than when the resistor/resistance of R_H is present,. Thus, with the exception/elimination of the resistor/resistance of R_H only insignificantly grow/rises the detected video voltage by the overall load of $R_{H,0}$ but considerably it is facilitated the execution of delay line.

The form of the amplitude characteristic of cascade/stage can be changed, by changing the stress of $E_{\text{сигн}}$. If in the diagram of multistage amplifier there are no resistor/resistances of R_H then to the stress level of separate cascade/stages to a certain degree can

affect the video voltage, which is isolated on overall load. In order to eliminate this effect, it is necessary to apply diodes with high internal resistor/resistance in opposite direction (vacuum-tube diodes, semiconductor diodes of the type of D2E and D2J) and to collect/build cascade/stages in the diagram of parallel anode feed.

Figure 98 shows the amplitude characteristic of the six-stage amplifier (curved 3), assembled on the tubes of 6J3P, without resistor/resistances R_3, R_8, \dots, R_{23} (Fig. 95), $\rho = R_5 = R_{25} = 600$ ohm and with the stresses of $E_{an_4} = 0,5$ V five cascade/stages and $E_{an_6} = 0,9$ V the sixth cascade/stage of the LAX of amplifier in this case also sufficiently precise in dynamic range 100 dB, but is somewhat shifted into the zone of high stresses.

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Diagram with separate detectors has the following advantages:

- 1). it is possible to obtain sufficiently precise LAX in wide dynamic range; 2). in the case of applying vacuum-tube diodes, is observed a small dependence of circuit parameters of circuit on temperature because of the absence of semiconductors. The stability of amplification and LAX of amplifier is determined by the stability of the parameters of amplifier tubes and vacuum-tube diodes.

To deficiency/lacks the diagrams are related: 1). the complexity and the need of careful adjustment. All amplifier stages

must be identical not only in the relation to the used in them tubes and diodes, but also in the relation to operational conditions, how this are allowed tolerances to network elements. The scatter of the component values and tubes substantially affects accuracy LAY; 2). in the case of application/use as the detectors of vacuum-tube diodes, the overall sizes of amplifier grow/rise. But if we use semiconductor diodes, then grow/rises the dependence of the circuit parameters of circuit on temperature.

The overall sizes of amplifier decrease, when the functions of the voltage amplification of high frequency and detection fulfills one tube.

Selective logarithmic amplifier with cathode detection.

In amplifier with cathode detection of the tube of amplifier, they are placed in the mode/conditions of amplification and cathode detection, so that each of the cascade/stages, except voltage amplification with the kolebairami of intermediate frequency and its supply to sledyushchemu cascade/stage, detects the stress of radio pulses and gives independent of other cascade/stages the component of the output stress of video pulse on overall load.

The simplified circuit of two cascade/stages on pentodes with cathode detection is shown in Fig. 100. The load impedance of cathode detector is the sufficiently high bias resistor of R_k into the cathode circuit of amplifier stage.

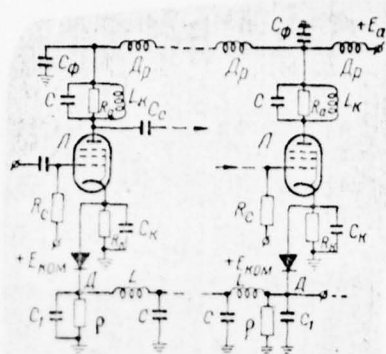


Fig. 100. The simplified circuit of logarithmic amplifier with cathode detection.

Operating point on anode-grid characteristic is selected just as in diagram with the gain control on envelope radiopul'sa. The required bias voltage is established/installed by supply in the circuit of the control electrode of the positive compensating voltage of E_{KOM} .

The resistor/resistance of R_k in high frequency is shunted by the capacitance/capacity of C_k . The time constant of the cathode circuit of $\tau_k = C_k R_k$ is selected from the condition of the execution of inequality (IV-16). Virtually the diagram of cascade/stage with cathode detection differs from diagram with gain control in pulse envelope only in terms of value of the resistor/resistance of R_k . The LAX of multistage amplifier in this diagram is obtained just as in diagram with separate detectors. From the cathode resistor/resistance of each cascade/stage, are remove/taken the detected voltages of the video pulses of positive polarity and enter delay line where store/add up themselves on overall load $R_{n.o} = \frac{p}{2}$. The detected voltage also is the voltage of the automatic gain control of this cascade/stage.

The simplest diagram with cathode detection possesses a series of the essential ndostatkov, basic from which they are: 1). the penetration of the voltage of video pulse from the cathode of each tube into the cathodes of all others. Because of this during saturation one of the cascade/stages, automatically changes the bias voltage in all amplifier stages. This phenomenon impedes the pobor of the necessary operating modes of cascade/stages and obtaining the LAX

of multistage amplifier in wide dynamic range; 2). the presence of the communication/connection between cascade/stages on video frequency, in consequence of which the amplifier works unstably and is inclined to self-excitation.

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For the elimination of these ndostatkov between the cathode of each tube of amplifier stage and the delay line it is possible to include/connect diode (is. 100), high resistor/resistance or separating cascade/stage. Diode must be switched on so that its resistor/resistance would be small for the passage of the current of the videoimul'sa, removed from the cathode of this tube, and large for the current of the video pulse, penetrating from other cascade/stages. If for the decoupling of cascade/stages are applied vacuum or semiconductor diodes, then as a result of the low values of resistor/resistance ρ and of the resistor/resistances of the diodes of resistor/resistance R_k in the cathode circuits of tubes are strongly zashchuntirovany, which leads to a decrease in the value of the detected video voltage and effect of the control of amplification in cascade/stages. The resistor/resistances of R_k will not shunitirovat'sya, if we instead of the diodes as the cell/elements of decoupling use high in value resistor/resistances. In this case strongly decreases the voltage of the video pulse, which enters the delay line, i.e., considerably decreases the transmission factor of cascade/stage in video voltage. From these ndostatkov is free the

diagram in which as the cell/elements of decoupling are applied the amplifier stages (cascade/stage-repeaters), with the aid of which it is possible not only to completely untie the cathode circuits of cascade/stages in high frequency, but also to correct the amplitude characteristic of n-cascade amplifier.

The schematic diagram of three cascade/stages (1st, 2nd and the 6th) of shestkaskadnogo amplifier with cathode detection and with cascade/stage-repeaters is depicted on *Fig. 101*. The resonance frequency of amplifier $f_0 = 30$ MHz.

Rassmorim the design procedure of logarithmic amplifier with cathode detection.

In order that the n-cascade amplifier would have a precise LAX over a wide range, the amplitude characteristics of cascade/stages with respect to video voltage must satisfy the requirement, presented in §2 chapter II. In their form these characteristics must be similar to curved, described equations (II-48), (II-50) and (II-52) (dashed curves in Fig. 13).

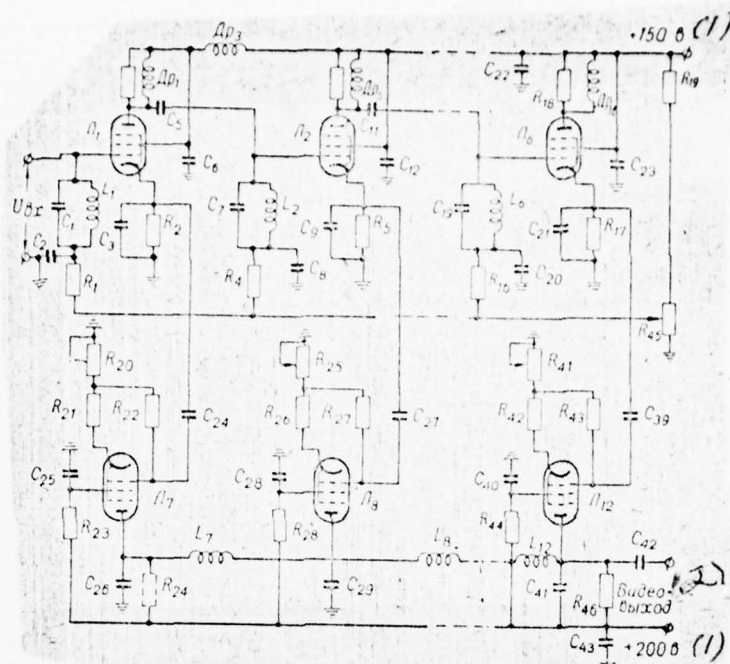


Fig. 101. Schematic diagram of resonance logarithmic amplifier with the cathode detection: L_1, L_2, \dots, L_{12} - 6J3P; R_1, R_4, R_{16} - 33 comas; R_2, R_5, \dots, R_{17} - 5 comas; R_3, R_6, \dots, R_{18} - 2.4 comas; R_{19} - 300 comas; R_{20} - 100 ohm; $R_{21}, R_{26}, \dots, R_{42}$ - 330 ohm; R_{25}, \dots, R_{41} - by ya"0om; $R_{22}, R_{27}, \dots, R_{43}, R_{45}$ - 100 ccmas; $R_{23}, R_{28}, \dots, R_{44}$ - 24 comas; R_{45}, R_{46} are 560 ohm; C_1 - 24 nf; C_2, \dots, C_{19} - 18 nf; $C_{24}, C_{27}, C_{42}, C_{39}$ - 0.05 μ F; C_{26}, C_{41} - 75 nf; C_{29} - 150 nf; L_7, L_8, \dots, L_{12} - 48 μ H; $C_3, C_6, C_9, C_{12}, C_{20}, C_{21}, C_{22}, C_{23}$ - 6800 nf; $C_{25}, C_{28}, \dots, C_{40}$ - 1 μ F.

Key: (1). V. (2). Video output.

For the calculation of the amplitude characteristics of cascade/stage with cathode detection according to the radio-voltage of

$U_{\text{blaxp}} = f(U_{\text{B}})$ and according to the video voltage of

$U_{\text{blaxB}} = \varphi(U_{\text{BX}})$ it is possible to use the dependences of

$E_{\text{CM}} = f(U_{\text{BX}})$ and $I_{\text{a1}} = f(U_{\text{BX}})$, depicted on Fig. 88 and 89. The detected video voltage in cathode circuit can be found from the curve of $E_{\text{CM}} = f(U_{\text{BX}})$, after taking the difference between that which flow E_{CM} and the initial E_{CMH} by bias voltages, i.e.,

$$U_{\text{blaxB}} = E_{\text{CM}} - E_{\text{CMH}}.$$

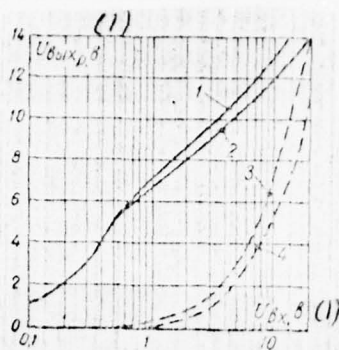


Fig. 102. Amplitude characteristics of cascade/stage with the cathode detection: 1. , 4. $R_K = 5$ comas, $E_{CMH} = -2 \text{ V}$; 2,

3. the $R_K = 10$ comas, $E_{CMH} = -2,5 \text{ V}$.

Key: (1) - V.

For sufficiently effective gain control in cascade/stage and obtaining the considerable rectified naporyazheniya, the resistor/resistance of R_k one should undertake the order of 5-10 ccmas. Figure 102 gives amplitude characteristics on radio- (curves 1 and 2) and to the video voltage (curves 3 and 4) of the separate cascade/stage with cathode detection, assembled on the tube of 6J3P, for two cases: the $R_k = 10$ comas and $E_{cmH} = -2,5$ V; the $R_k = 5$ comas and $E_{cmH} = -2$ V. Characteristics 1 and 2 are designed with maksimal'nom factor of amplification $K_1 = 10$. For this, as can be seen from Fig. 89, the common/general/total and one of the resistor/resistance of cascade/stage in the first case must be 2 ccmas, in the second - 1.3 ccmas.

The characteristics on the video voltage of separate cascade/stage are linear. In multistage amplifier each kadekadu precedes another cascade/stage with the amplitude characteristic on radio-voltage, which has logarithmic section. As a result of this, all cascade/stages, with the exception of the first, have amplitude characteristics on video voltage depending on entry stress of amplifier also with logarithmic section. This one can see well from Fig. 103, in which are shown amplitude characteristics the video voltage of the cascade/stages of six-stage amplifier. Along the axis of abscissas, is deposited/postponed the entry stress of amplifier. Index i the figure indicates the reference number of cascade/stage. Characteristics are designed on curve, depicted on Fig. 102 for two cases of $R_k = 10$ and 5 comas.

The characteristics, given in Fig. 103, coincide sufficiently well in form with dashed curve in Fig. 13 (case $a = 1$), which indicates the possibility of obtaining precise by the LAX of amplifier over a wide range. Figure 104 shows the amplitude characteristics of entire amplifier (curves 1 and 2), obtained by the addition of the ordinates of the characteristics of cascade/stages from video voltage (Fig. 103) not allowing for the transmission factor of cascade/stage-repeaters.

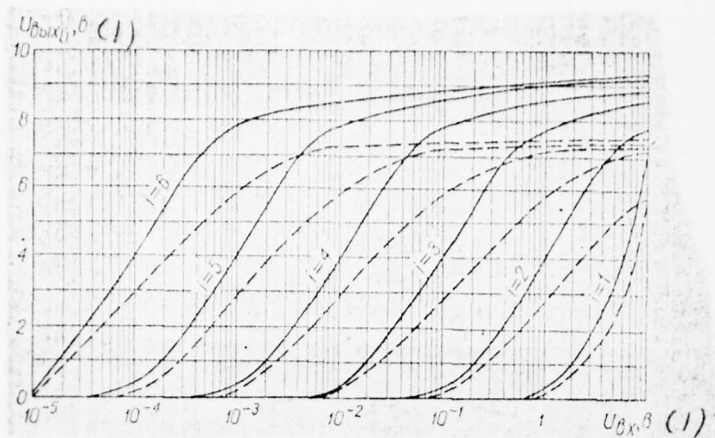


Fig. 103. Amplitude characteristics on the video voltage of cascade/stages with cathode detection in the joint operation: the

— $R_K = 10$ comas, $E_{\text{cmH}} = -2,5 \text{ V}$;
 --- $R_K = 5$ comas, $E_{\text{cmH}} = -2 \text{ V}$.

Key: (1). V.

Figure 104 shows that in both cases the amplitude characteristics of amplifier with high input voltage differ from the logarithmic as a result of linearity amplitude characteristic of the 1st cascade/stage. This deflection of the characteristic of amplifier can be removed, after supplying 1-1 cascade/stage-repeaters in mode/conditions with peremenym transmission factor. All remaining cascade/stage-repeaters must have constant transmission factor for sufficiently high input voltage. Thus, for instance, for the first case of the

($R_k = 10$ comas) the maximum input voltage of repeaters is equal 9.1c (Fig. 103), and in the second ($R_k = 5$ comas) - 7.4 V. In the amplifier, printspial'naya diagram of which is depicted on Fig. as 101, the mode/conditions of repeaters in both cases are selected as follows: repeaters from the second to the sixth have the transmission factor of $k_n = 0.5$ to the input positive video voltage of $U_{bx_B} = 7$ v and an $k_n = 0.4$ to $U_{ex_B} = 9.5$; the first repeater has $k_n = 0.5$ to $U_{bx_B} = 3$ v and $k_n = 0.25$ to $U_{bx_B} = 10$ V.

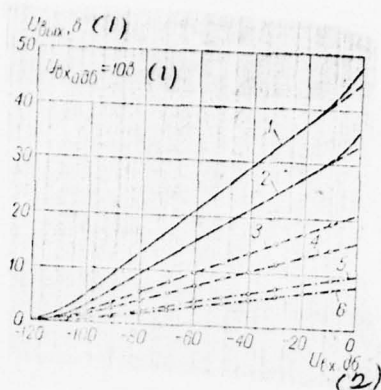


Fig. 104. Amplitude characteristics of rezonansnogo logarithmic amplifier with the cathode detection: 1. , 3. , 5.

$$R_k = 10$$

$$\text{comas, } E_{\text{cmH}} = 2.5 \text{ V};$$

$$2, 4, 6. - R_k = 5$$

comas;

$E_{\text{cmH}} = -1 \text{ V}$; 1, 2. not allowing for the transmission

factor of k_n ; 3, 4. with consideration the coefficient of k_n and during the agreement of line from one end/lead; 5, 6. with consideration the coefficient of k_n and during the agreement of line from two end/leads.

Key: (1). V. (2). dB.

In order that the cascade/stage-repeaters would pass with the constant coefficient of predachi high input voltage, in them was applied sufficiently deep negative feedback. The resistor/resistances of feedback in these cascade/stages are taken by variables.

it is known that the amplifier tubes have the large scatter of the parameters. Because of this amplitude characteristics in the video voltage of different cascade/stages strongly differ and the experimental LAX of amplifier it has considerable deflections from precise. by changing the values of the resistor/resistances of feedback in cascade/stage-povotritel4x, possible sufficiently lgko to obtain identical characteristics from video voltage at the output/yield of these cascade/stages and, consequently, also high accuracy the LAX of amplifier with the large scatter of the parameters of tubes.

Delay line in both cases ($R_K = 10$ and 5 ccomas) was applied one and the same with these parameters: the inductance of component/link $L = 48 \mu H$, the capacitance/capacity of component/link $C = 150 \text{ nf}$, wave impedance $\rho = 560 \text{ ohm}$, the delay time one component/link of

$t_{d, n} = 8,5 \cdot 10^{-8} \text{ s}$, that corresponds to delay time in cascade/stage in passband $\Delta F_1 = 3.8 \text{ MHz}$. The corresponding passband in cascade/stages begred by the inclusion of series capacitor into oscillatory plate circuits. Fundamental amplifier circuit Fig. 101 gives for the case of the $R_K = 5$ ccomas. In the target/purpose of an increase in the transmission factor of repeaters, the delay line was agreed with one end/lead, output. In this case, reflections in

the line and of the distortions of video pulse were not observed. Previously are shown the transmission factors of repeaters during the agreement of line with the odngo of end/lead. During the agreement of line from two end/leads, the transmission factors of repeaters decreased two times.

Figure 104 gives the experimental amplitude characteristics of six-stage amplifier during the agreement of line from one end/lead (curves 3 and 4) and from two end/leads (curves 5 and 6). From this figure it is evident that the LAX of amplifier in the range to 100 dB has an accuracy not worse than 2-3o/o; during careful adjustment the accuracy LAX can be obtained by 1-2o/o. Range real by LAX increased in comparison with calculated because of the limiting action of the first potoritelya.

Diagram with cathode detection has the following advantages: 1). it is possible to obtain a precise LAX in wide dianimcheskom range; 2). it has the high stability of amplification and LAX, caused deep COS on direct current in resonance cascade/stages and a OOS on alternating and direct currents in cascade/stage-repeaters, and also by the absence of semiconductor nonlinear cell/elements.

To deficiency/lacks can be attributed the complexity of diagram and the increased overall sizes of amplifier.

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Resonance logarithmic amplifier with anode rectification.

In amplifier with the anode rectification of the tube of amplifier stages, they are placed into the mode of the simultaneous voltage amplification of high frequency and anode rectification. The simplified circuit of two cascade/stages with anode detaktirovaniyem is depicted on Fig. 105. In these cascade/stages plate load in high frequency are the two-circuit filters. Analogously can be applied single resonant circuits. The resistor/resistances of R_n connected in series with plate circuits, are the load resistor/resistances, during which are isolated the detected video pulses of negative polarity. These momentum/impulse/pulses enter delay line and store/add up themselves during the total resistance of

$R_{n.0} = \frac{\rho}{2}$. The capacitance/capacity of C_n blocks the sorotivleniye of R_n in high frequency.

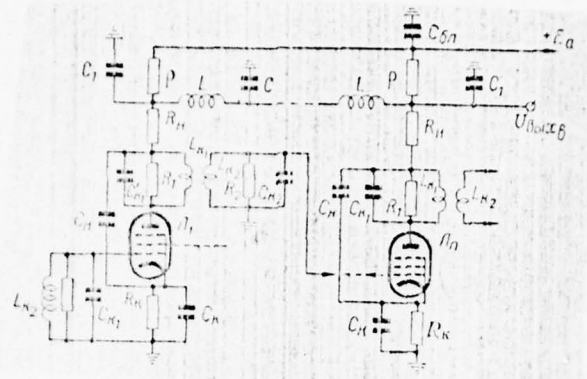


Fig. 105. The simplified circuit of selective usiletelya with anode rectification.

The time constant of the load circuit of the detector of $\tau_a = C_a R_k$ is selected from the condition of the permissible distortions of video pulse.

In diagram with anode rectification, it is expedient to utilize a pentode with the short characteristic, which has the sharp cutoff of anode current. Operating point ustanovlivaetsya approximately in the middle of the curvilinear section of characteristic with the pomosh'yu of the source of constant negative displacement or corresponding resistor/resistance of R_k . During the indicated selection of operating point, the angle of cutoff of anode current is changed during a change in the value of vkhodnogo voltage. Consequently, the transmission factor of the plate rectifier of k_R in this case also is changed from zero with low signals to the completely determined value at large signals. In this case, the factor of amplification of cascade/stage in radio-frequency with an increase of signal decreases, since decreases the slope/transconductance of tube in fundamental harmonic of anode current and increases by-passing the subsequent tube on plate load as a result of an increase in the grid currents.

During the low resistor/resistances of R_k the automatic gain control on pulse envelope is not effective. with large signals the kaskad is overloaded and they appear considerable grid currents, which leads to an increase in the inertness of diagram.

For the elimination of this deficiency/lack, it is expedient in the cathode circuit of cascade/stage to include the high resistor/resistance of R_k , selected from the condition of obtaining a good gain control in the same way as this is made in diagram with gain control on pulse envelope or with cathode detection. In this case considerably is simplified the calculation of amplifier from LAX and for its calculation it is possible to utilize curves, depicted on Fig. 89.

In diagram with anode detekrirovaniyem, the resistor/resistance of R_n can no in principle (Fig. 105). In this case, the delay line must provide a good razvyaku in vysokoy frequency between cascade/stages. In the absence of the resistor/resistance of R_n video pulse is isolated directly during the resistor/resistance of p , a its distortion with sufficiently broadband delay line are determined by the time constant of the cathode circuit of $\tau_k = C_k R_k$. The voltage of the video pulse, which enters from the output/yield of each cascade/stage, in the case of the agreement of line from two end/leads

$$U_{\text{blax}_B} = I_B \frac{p}{2} = (I_{a, n} - I_{a, nH}) \frac{p}{2}, \quad (\text{IV-35})$$

where the $I_{a, n}$ is a feed current, which in the case of the approximation of the anode-grid characteristic of tube by hyperbolic tangent is determined from formula (IV-20);

$I_{a. nH}$ are the initial value of the constant of the sostavlyayuy of anode current;

I_b - an increment postonnoy component of anode current during a change in the signal.

During the agreement of line from one end/lead

$$U_{BHX_B} = I_B \rho. \quad (IV-36)$$

The voltage in high frequency on the output/yield of cascade/stage is determined analogous with diagram with gain control from ogibayuey radio pulse. Amplitude characteristics on radio- and to the video voltage of cascade/stage with anode rectification during the appropriate mode/conditions in form are analogous to the characteristics, given in Fig. 89, 102 and 103. Consequently, the procedure for calculation and design of logarificheskogo amplifier with anode rectification is analogous to the design procedure of amplifier with cathode detection.

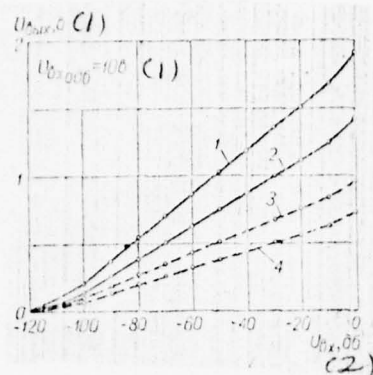


Fig. 106. Amplitude characteristics of resonance logarithmic amplifier with the anode rectification: 1, 3. $R_K = 10$ comas; 2, 4. $R_K = 5$ comas; 1, 2. during the agreement of line from one end/lead; 3, 4. during the agreement of line from two end/leads.
Key: (1). V. (2). DB.

Figure 106 shows the amplitude characteristics of six-stage amplifier with anode rectification and with single resonant circuits in the anode circuits of cascade/stages. fundamental amplifier circuit is assembled on the base of the diagram, depicted on Fig. 101. Amplifier has the following data: the passband of the cascade/stage of $\Delta F_1 = 3.8$ MHz; the maximum factor of amplification of the cascade/stage of $K_1 = 10$; the general passband of amplifier $\Delta F = 1.2$ MHz; in the cathode circuits of cascade/stages are placed the resistor/resistance of $R_k = 5$ and 10 ccoms; delay line is used the same as in diagram with cathode detekritcvaniyem. Figure 106 shows that the range the LAX of amplifier was shortened to 10 en. and rezul'tiroyushcheye output voltage 25 times less than in the case of amplifier with cathode detection. Range reduction of the LAX of amplifier is explained by the linearity of amplitude characteristic on the video voltage of the 1st kaskala. Accuracy LAX with the appropriate selection of tubes with small scatter of the parameters and during the rshchatel'noy adjustment of amplifier can be obtained by 2-3o/o.

To the advantages of diagram with anode rectification can be attributed:

- 1) the possibility of obtaining LAX in wide dynamic range;
- 2) the stability of amplification and LAX, caused deep OOS with direct current and by the absence of semiconductor nonlinear cell/elements;

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3) comparatively small overall sizes of amplifier in view of the absence of separate detectors and cascade/stage-repeaters.

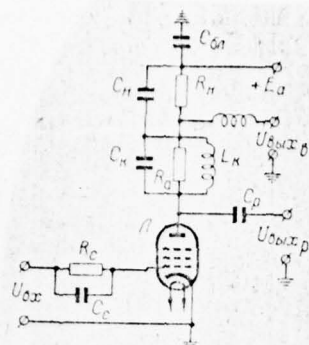


Fig. 107. The simplified circuit of cascade/stage with grid detection.

Deficiency/lacks the diagrams are:

- 1) small output video voltage;
- 2) the tendency of diagram toward self-excitation as a result of the parasitic interstage communication/connection through the delay line.

Resonance logarithmic amplifier with grid detection.

In amplifier with the grid detection of tube, they place in the mode/conditions of simultaneous amplification and grid detection. the simplified circuit of cascade/stage in the work of tube under these conditions is depicted on Fig. 107. Diagram works as follows. During the supplying to the input of continuous high-frequency oscillations during the resistor/resistance of R_c with the course of grid currents, is isolated the negative bias voltage of E_{cm} , which it grow/rises and it displaces operating point on the plate characteristic of tube with an increase of input voltage. This leads to a change constant component $I_{a.0}$ and the fundamental harmonic of the $I_{a.0}$ of anode current. If we to input feed radio pulses, then during resistor/resistance R_c will be isolated the video pulses of negative polarity and amplified in anode circuit.

Detection occurs as a result of the nonlinearity of the characteristic of the grid cathode current of $i_c = f(U_c)$. Thus, in cascade/stage simultaneously occurs detection of the voltage of

radio-frequency, voltage amplification of the video-i of radio-frequency and the control of the amplification of cascade/stage during an increase in the input voltage. Plate load on video frequency is the resistor/resistance of R_{ii} shunted on radio-frequency by the capacitance/capacity of C_{ii} . Plate load on radio-frequency is the plate circuit.

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The resistor/resistance of R_c shunted by the capacitance/capacity of C_c which must be selected, on one hand, from the condition of the maximum transmission of the applied voltage of radio-frequency to section grid - the cathode of tube, on the other hand, from the condition of obtaining the sufficiently fast time constant of

$\tau_c = R C_c$. This constant causes the discharge time of the capacitance/capacity of C_c and, consequently, the recovery time of the maximum sensitivity of amplifier after the break-down of large signal.

For the indicated mode of amplification, it is necessary to apply the tubes, which have sufficiently large grid currents with negative voltages on control electrode. Such tubes include the pentodes of the type of 6J1P, 6J1B and 6J3P. Figure 49 shows the experimental grid characteristics of the pentode of 6J1P with different voltages on the screen grid of U_{s1} . The grid characteristics of the tube of 6J1P have a good recurrence, which is necessary for obtaining precise by

the LAX of n-cascade amplifier.

Pentode 6J1B has the grid currents, comparable with the currents of the pentode of 6J1P. Of the pentode of 6J3P, the grid currents 2-3 times are less than of the pentode of 6J1P. By applying such pentodes, it is possible to obtain sufficiently high initial bias voltage and power capacity of scattering on the anode in the absence of entry stress.

briefly we examine diagram and will examine the procedure for its design. In this case, must be found the dependences of a change in the bias voltage on the control electrode of the $E_{cm} = f(U_{bx})$, of the amplitude of the fundamental harmonic of the anode current of the $I_{a1} = f(U_{bx})$, of the feed current of $I_{a.n}$ and difference in the currents of $I_B = I_{a.nH} - I_{a.n} = \varphi(U_{bx})$ from the amplitude of the input voltage of U_{bx} . In order that for a circuit analysis it was possible to use mathematical apparatus, necessary anode $i_a = f(U_c)$ and the grid $i_g = f(U_g)$ of the characteristic of tubes to approximate by which that curves.

The plate characteristic of tube it is most expedient to approximate by hyperbolic tangent. With the approximation of the experimental plate characteristic of the tube of 6J1P, is taken: the $I_{a0} = 14,8$ mA; $S = 4.5$ mA/V; $q_a = 0,3$; $p = 1.15$. The given approximation sufficiently accurately reproduces plate characteristic during a change in stress U over wide limits (Fig. 86, is curve 5).

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Grid characteristic it is most expedient to approximate by exponential function (II-113) (see Fig. 49). When, on the control electrode, the tube of alternating/variable sine voltage is present, the constant component of the grid current

$$I_{c, n} = \frac{I_{\text{макс}} + I_{\text{мин}}}{6} + \frac{I_1 + I_2}{3}$$

can be determined sufficiently accurately by the method five ordinates.

Since

$$I_{\text{макс}} = I_{c_0} e^{a(U_{\text{BX}} - E_{\text{CM}})};$$

$$I_{\text{мин}} = I_{c_0} e^{-a(U_{\text{BX}} + E_{\text{CM}})};$$

$$I_1 = I_{c_0} e^{a\left(\frac{1}{2}U_{\text{BX}} - E_{\text{CM}}\right)};$$

$$I_2 = I_{c_0} e^{-a\left(\frac{1}{2}U_{\text{BX}} + E_{\text{CM}}\right)};$$

$$I_{c, n} = I_{c_0} \left\{ \frac{1}{6} [e^{a(U_{\text{BX}} - E_{\text{CM}})} + e^{-a(U_{\text{BX}} + E_{\text{CM}})}] + \right. \\ \left. + \frac{1}{3} [e^{a\left(\frac{1}{2}U_{\text{BX}} - E_{\text{CM}}\right)} + e^{-a\left(\frac{1}{2}U_{\text{BX}} + E_{\text{CM}}\right)}] \right\}.$$

After simple conversions we will obtain

$$I_{c, n} = \frac{I_{c_0}}{3} e^{-aE_{\text{CM}}} \left[\text{ch } aU_{\text{BX}} + 2 \text{ch } \frac{aU_{\text{BX}}}{2} \right].$$

Taking into account that bias voltage on the grid of $E_{\text{CM}} = I_{c, n} R_{c_0}$, we

will obtain

$$E_{cm} = \frac{I_{cs} R_c}{3} e^{-a E_{cm}} \left(\operatorname{ch} a U_{bx} + 2 \operatorname{ch} \frac{a U_{bx}}{2} \right).$$

Multiplying both parts of obtained equation on coefficient a also introducing for an abridgement in the designation of $\alpha = a E_{cm}$ and $A = \frac{1}{3} a I_{cs} R_c \left(\operatorname{ch} a U_{bx} + 2 \operatorname{ch} \frac{a U_{bx}}{2} \right)$, we come to the equation

$$\alpha e^{\alpha} = A. \quad (\text{IV-37})$$

By solving this equation, it is possible to find analytical expression for the bias voltage of E_{cm} at the rated value of the amplitude of the input voltage of U_{bx} .

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The equation (IV-37) is transcendental and it is possible to solve approximately. Moreover tselessobrazno to find two solution for low and great significance α .

Let us find the solution for $\alpha \leq 0.5$, is decomposed the left side of the expression (IV-37) in the series

$$\alpha e^{\alpha} = \alpha + \frac{\alpha^2}{1!} + \frac{\alpha^3}{2!} + \frac{\alpha^4}{3!} + \dots \quad (\text{IV-38})$$

For $\alpha < 0.5$ with the accuracy of the solution not less than 100% it is possible to be restricted to two terms of expansion. After the substitution of resolution (IV-38) into equation (IV-37) we have

$$a E_{cm}^2 + E_{cm} - A = 0.$$

Then the solution to equation takes the form

$$E_{cm} = \frac{\sqrt{1+4aA}-1}{2a}. \quad (IV-39)$$

with $U_{bx} = 0$ are the initial voltage of the seshcheniya

$$E_{cmH} = \frac{\sqrt{1+4a^2I_{cs}R_c}-1}{2a}. \quad (IV-40)$$

Now let us find the solution to equation (IV-37) for $\alpha \leq 2$.

Introducing the designation of $y = e^x$, we obtain $y \ln y = A$.

Taking into consideration that at sufficiently great significance α ($\alpha \gg 2$, $y \gg 5$) with a sufficient degree of accuracy is fulfilled the equality of $\ln y \approx \sqrt[3]{y}$, we have an $y \sqrt[3]{y} = A$, whence

$$\alpha = \frac{3}{4} \ln A.$$

Thus, finally we obtain

$$E_{cm} = \frac{3}{4a} \ln \left[\frac{a}{3} I_{cs} R_c \left(\operatorname{ch} a U_{bx} + 2 \operatorname{ch} \frac{a U_{bx}}{2} \right) \right]. \quad (IV-41)$$

With the $U_{bx} = 0$

$$E_{cmH} = \frac{3}{4a} \ln a I_{cs} R_c. \quad (IV-42)$$

For the solution to equation (IV-37) in values $0.5 \leq \alpha \leq 2$ it is

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possible to be average values of solutions (IV-37) and (IV-41).

Equation (IV-37) sufficiently accurately can be solved graphically.

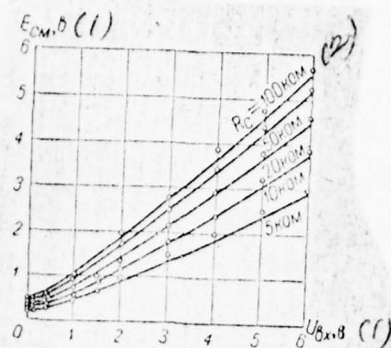


Fig. 108. Curves of the zavismosti of a change in the bias voltage from the value of the amplitude of input signal.

Key: (1). V. (2). KSM.

Constant component $I_{a, n}$ and the fundamental harmonic of the $I_{a, n}$ of anode current are determined from formulas (IV-20) and (IV-24). Since with an increase in the input signal constant component $I_{a, n}$ decreases, the value of the rectified current, which determines video voltage on the load of R_H , one should determine from the formula

$$I_B = I_{a, n_H} - I_{a, n} \quad (IV-43)$$

The voltages of the radio-frequency of $U_{B\Omega X_D}$ and video frequency on the output/yield of cascade/stage for the diagram in question are determined from formulas (IV-25) and (IV-35).

Figure 108 depicts calculated curve $E_{cm} = f(U_{BX})$ for the tube of 6J1P at the different values of the resistor/resistance of R_c . The calculation is produced for the mode/conditions of the tube of $U_a = U_s = 120 \text{ V}$ with the voltages of $U_a = U_s = 100 \text{ V}$ $E_{cm} = f(U_{BX})$ insignificantly they differ to the large side of E_{cm} from curves, depicted on Fig. 108. This excess it composes at the values of $U_{BX} = 4 \div 6 \text{ V}$ not more than 2-40/o. For obtaining the larger accuracy of the calculation of the voltage of E_{cm} the equation (IV.37) is solved graphically. Check calculations showed that according to formula (IV-39) in this case it is expedient to design E_{cm} with input voltage from 0 to 0.5 in and from the formula (IV-41) - with input voltage from 0.5 v and above. In this case, an error in the calculation does not exceed 3-50/o. In this same figure are shown experimental points.

Figure 108 shows that sufficiently the actual stress of E_{cm} changes during the resistor/resistances of the $R_c \geq 50$ of comas. At the values of the resistor/resistance of the $R_c \leq 50$ of comas and with the considerable amplitudes of input voltage in view of the smallness of the voltage of E_{cm} flow/last large grid currents, which leads to the powerful shntircvaniyu of the plate load of the preceding/previous cascade/stage.

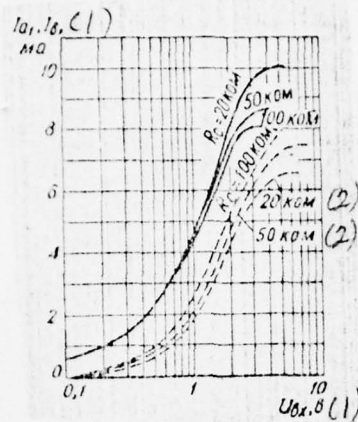


Fig. 109. Curves of the dependences of a change in the fundamental harmonic of anode current and constant component on the value of the amplitude of input signal during the grid detection:

$$\begin{aligned} \text{---} I_{a1} &= I(U_{bx}); \\ \text{---} I_{d1} &= \varphi(U_{bx}). \end{aligned}$$

Key: (1). mA. (2). Anyone.

Consequently, in order that by-passing the input of tube would be insignificant, for the tube of 6J1P it is necessary to apply the resistor/resistances of the $R_c \geq 50$ cf comas.

Figure 109 for three values of the resistor/resistance of R_c by solid lines depicts curved $I_{a1} = f(U_{bx})$, a prime, i.e., curved $I_{a1} = \varphi(U_{bx})$, calculated from formulas (IV-24) and (IV-43). During the calculation were utilized the data given in Fig. 107, and the approximation of the plate characteristic of tube by the expression

$$i_a = 14,8 \cdot 10^{-3} (1 - \text{th } 3,45 U_c).$$

From Fig. 109 it follows that the curved $I_{a1} = \varphi(U_{bx})$ by nature coincide sufficiently well with dashed curve in Fig. 13 (case $a = 1$). The expected dynamic range the LAX of one cascade/stage will be greatest with the $R_c = 100$ of comas and by approximately equal to

$$D_1 = \frac{U_{bx1}}{U_{bx1}} = \frac{8g}{1g} = 8.$$

Consequently for obtaining accurate MAX of the n-cascade amplifier the amplification factor of one cascade should be $K_1 = D_1 - 1 = 8 - 1 = 7$.

Since the amplitude of the first harmonic of anode current I_{a1} when $U_{bx} = 0,1$ V (fig. 109), is equal to 0.5 mA, then for obtaining $K_1 = 7$ the total anode resistance to current I_{a1} should be equal to

$$R_{a1} = \frac{K_1 U_{bx}}{I_{a1}} = \frac{7 \cdot 0,1}{0,5 \cdot 10^{-3}} = 1,4 \cdot 10^3 \Omega$$

With total stray capacitance in the anode circuit $C_0 = 30$ nf the passband of one cascade/stage

$$\Delta F_1 = \frac{1}{2\pi C_0 R_{a1}} = 3,8 \text{ MHz.}$$

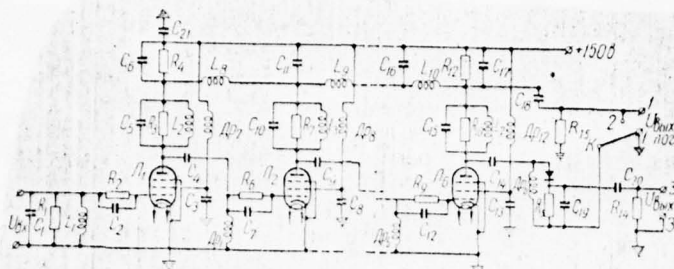


Fig. 110. Schematic diagram of resonance logarithmic amplifier with the grid detection:

$T_1, T_2, \dots, T_3 - 6Ж111$; $R_1, R_2, R_3, \dots, R_{10} - 1,8 \text{ КОМ}$; $R_4, R_5, \dots, R_8 - 100 \text{ КОМ}$; $R_9, R_{10} - 500 \text{ КОМ}$; $R_{11} - 10 \text{ КОМ}$; $R_{12} - 100 \text{ КОМ}$; $C_1 - 27 \text{ нФ}$; $C_{11} - 9,00 \text{ нФ}$; $C_2, C_3, \dots, C_{10} - 51 \text{ нФ}$; $C_4, C_{10}, \dots, C_{13} - 22 \text{ нФ}$; $C_5, C_6, C_{13} - 910 \text{ нФ}$; $C_{11}, \dots, C_{14} - 150 \text{ нФ}$; $C_7, C_{11} - 75 \text{ нФ}$; $L_1, L_2, \dots, L_{10} - 48 \text{ МГН}$; $C_8, C_9, \dots, C_{14} - 200 \text{ нФ}$; $C_{15} - 0,1 \text{ МГН}$.

In this case, the time lag of signal in one cascade/stage of

$$t_{s, K} = 8,5 \cdot 10^{-5} \text{ s.}$$

TAB Fig. 110 shows the schematic diagram of the six-stage amplifier, assembled on the tubes of 6J1P. The resonance frequency of amplifier $f_0 = 30 \text{ MHz}$. For obtaining the identical parameters in all six cascade/stages are selected six identical tubes from party/batch 20 pcs. Tubes were take/selected on anode I_a and grid I_g to the currents with of $E_{cm} = 0$ also, on the cutoff voltage of E_{san} . The scatter of the parameters was allow/assumed not more than 50/o. In the grid circuits of cascade/stages, are included the resistor/resistances of the $R_c = 100$ of comas and capacitance/capacity of $C_c = 51 \text{ nf}$. The factor of amplification of each cascade/stage, measured at point after the chain/network of $R_c C_c$ is driven on under the calculated $K_1 = 7$ by selection of the corresponding value of anode resistor/resistance. In this case, the general passband of amplifier $\Delta F = 1.05 \text{ MHz}$.

The particular loads (resistor/resistance of aaaaa) on video voltage from the anode circuits of cascade/stages, are excluded. Overall load on video voltage are two matched impedances R_4 and R_{12} , the connected on dead endings of delay. The total load of

$$R_n = \frac{R_4}{2} = 280 \text{ } \Omega.$$

Figure 111 depicts the calculated on radio-voltage amplitude characteristic of one cascade/stage with of the $R_c = 100 \text{ } \Omega$ of comas (is curve 1).

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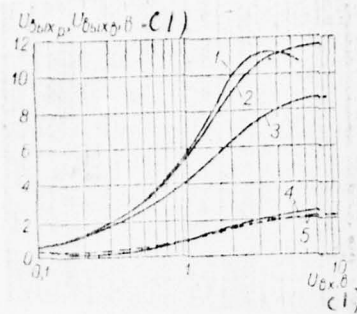


Fig. 111. Amplitude characteristics of cascade/stage by grid detection.

Key: (1). V.

In this same figure are shown experimental amplitude characteristics the radio-voltage of one cascade/stage with cff (is curve 3) subsequent cascade/stage. Curves 2 and 1 do not coincide well which testifies to the correctness of calculation procedure for calculation. From the analysis of curve 3 it is evident that even at the value of the resistor/resistance of the $R_c = 100$ of comas with high input voltage pronounces by-passing the subsequent cascade/stage. It is logical, chtopri the lesser resistor/resistances of R_c shunting deystviyeposleduyushchego cascade/stage it develops itself in larger measure. On this same figure are depicted the amplitude characteristic of cascade/stage on video voltage (is curve 4) for an $R_{H.o} = 280$ the ohm, the calculated from the curve of $I_u = \varphi(U_{BX})$ with $R_c = 100 \text{ KOM}$, and trebuyemya the amplitude characteristic (curved 5), calculated from formulas (I-5), (I-52) and (I-54) for case $K_1 = 7$; $D_1 = 8$; $a = 1$; $U_{BX} = 1V$ curves 4 and 5 very well coincide in all expected range of a change in the input voltage of cascade/stage, which indicates the possibility of obtaining precise by the LAX of entire amplifier in wide dynamic range.

Figure 12 shows three amplitude characteristics of six-stage experimental amplifier, obtained during the measurement of output voltage on different output terminals and in the different position of key/wrench K. Amplitude characteristic 1 is obtained during the measurement of output load voltage 1-1 (it is direct on the load of delay line) and during the determination of key/wrench K in position of 1 (Fig. 110). In this case the experimental characteristic of amplifier coincides sufficiently well with precise by LAX in dynamic

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range in input voltage $D = 94$ dB. Relative deflection real by LAX
from precise in all range 94 dB compses not more than 30/o.

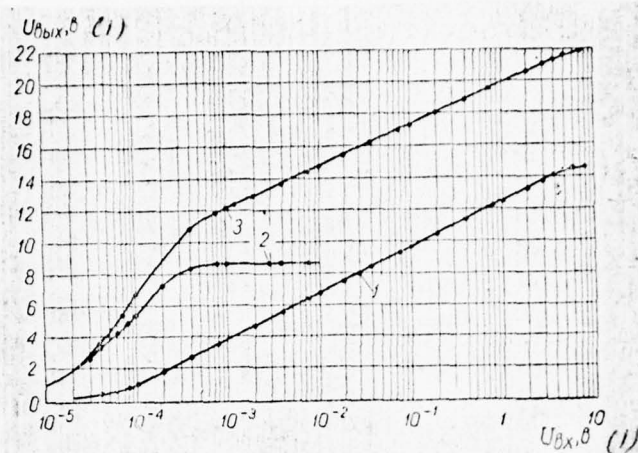


Fig. 112. Amplitude characteristics of resonance logarithmic amplifier with grid detekrivaniyem.

Key: (1). V.

Upon the arbitrary replacement of the tubes of amplifier from party/batch 20 pcs., the relative deflection of experimental characteristic from precise logarithmic in certain cases reached to 100/o.

A deficiency/lack in characteristic 1 is znaizhennaya sensitivity of amplifier. This sensitivity will be significantly higher, if we measure the output load voltage 3-3. Amplitude characteristic 2 (characteristic of the last/latter cascade/stage) is obtained during the measurement of vykhodnna grippers 3-3 and during the determination of key/wrench K in position of 1. In etcm sluchae the limitation of the output voltage begins with small input voltage. Amplitude characteristic 3 is obtained during the measurement of output load voltage 3-3 and during the determination of key/wrench K in position of 2. Characteristic 3 is a result of the addition of characteristics 1 and 2 and in form is linear-logarithmic. In this case the sensitivity sharply increased, but dynamic range the LAX of amplifier was shortened to 74 dB.

Accurately thus it is possible to increase the sensitivity of the lyubogousilitelya in which the LAX is obtained according to the method of consecutive detection.

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Thus when it is required to obtain the greatest dynamic range precise by the LAX of amplifier (for metering equipment), output

voltage it is necessary to remove/take neposredtvenno from the load of delay line. For the polucheni of the mksimal'ncy sensitivity of usilitlya output napryazheiy must be remove/taken from the load of the detector, connected at the output/yield of the last/latter cascade/stage. In this case, the general nagruzkaya kaskadv on video voltage (load of delay line) must be included consecutively with the load of detector.

one of the essential deficiency/lacks in the examined method of obtaining LAX is the inertness of amplifier after the predrashcheniya of leystviya are large signals, caused sufficiently slow response of the τ_c of the circuit of $R_c C_c$ in each cascade/stage. Thus, for instance, in the amplifier, schematic diagram of which is depicted on Fig. 110, the time constant of τ_c is equal to $5.1 \cdot 10^{-6}$ s. Consequently, the capacitor discharge time of $t_{\text{pass}} = 10 \div 15$ ns. capacitance/capacity of τ_c is cannot, since on it will vyddlyat'sya the considerable part applied radio frequency voltage. It is necessary to note that time of the charge of the capacitance/capacity of C_c with larger signals ten times less than the discharge time of t_{pass} , since the input impedance of a tube in this case composes kilohm.

The second deficiency/lack is the criticality of diagram to the exchange of amplifier tubes.

The advantage of diagram is the possibility of obtaining LAX in

wide dynamic range. Diagram with grid detection can be successfully applied in equipment/devices from the LAX, intended for amplification continuous oscillations and the radio pulses, following each other through time intervals not less than 15-20 μ ss.

In all examined diagrams with the consecutive addition of voltage is inherent the common deficiency/lack: with powerful signals the vlstedstviye of the "disconnection" of certain number of last/latter stages of amplifier and their overloading expands itself the passband. This causes a decrease in the set-up time of momentum/impulse/pulse at the output of amplifier during an increase in the input signal.

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CHAPTER FIVE

TRANSIENT PROCESSES IN APERIODIC AND SELECTIVE LOGARITHMIC AMPLIFIERS.

Any logarithmic amplifier is nonlinear. This Vsledtviye the transient processes, which take place in logarithmic amplifiers, have a series of special feature/peculiarities. To such special feature/peculiarities one should relate:

1. Sharp decrease in the time lag of momentum/impulse/pulse at the output of amplifier during an increase in the input signal.
2. Considerable increase in the decay in the flat/plane pulse apex and parasitic reverse/inverse vyborosa at the output/yield of logarithmic video amplifier with an increase in the signal.

The formation/education of large reverse/inverse overshoot impedes the practical use of logarithmic video amplifiers with dynamic range more than 60 dB. The appearance of considerable decay in the

flat/plane pulse apex at the end of the range of LAX causes dopolnite'noye deflection experimental by LAX from accurately logarithmic.

In the present chapter are examined transient processes in the standard diagrams of logarithmic amplifiers and are shown the possible circuit solutions which make it possible to umenshit' the distortion of the pulse signal, uslivaemogo by logarithmic amplifier.

§1. Transient processes in logarithmic video amplifier. Single-stage amplifier.

The equivalent diagram of nonlinear cascade/stage is depicted on Fig. 113.

The conductivity of aaaaa on equivalent diagram can no, since in many instances of the function of leakage resistance it makes nonlinear cell/element.

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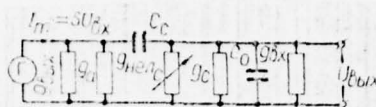
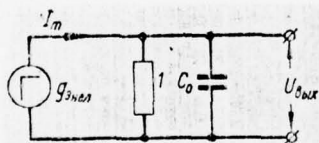


Fig. 113. The equivalent diagram of the nonlinear cascade/stage:

g_a - the conductivity of anode resistor/resistance; g_{nl} - the conductivity of nonlinear cell/element; g_{bx} and g_{bx} - with respect to the output and input admittance of tubes; g_c - the conductivity of the leakage resistance of C_c ; C_c are a transient capacitance/capacity; C_o - the stray capacitance, which shunts plate load.

Fig. 114. Equivalent diagram of nonlinear cascade/stage for the range of higher frequencies.



Transient processes we will examine on the assumption that at point in time $t = 0$ the input of nonlinear cascade/stage affects the voltage surge of $U_{\text{вх}}$.

Since the iskazhniya of pulse edge they obuslovlivatsya by the network elements, which determine the frequency characteristic of cascade/stage in the range of higher frequencies, and the distortion of flat/plane pulse apex - by the network elements, opredelyayushchimi frequency characteristic in the range of lowest frequencies, it is expedient on the common equivalent diagram of cascade/stage to isolate equivalent diagrams for higher and lowest frequencies and to examine separately transient processes in each of these diagrams.

Distortions of pulse edge.

The equivalent diagram of nonlinear cascade/stage for the range of higher frequencies is depicted on Fig. 114, in which

$$g_{\text{вкл}} = g_a + g_{\text{вкл}_c} + g_{\text{вкл}_s} + g_{\text{вкл}_d} + g_c.$$

Under the influence on the input of nonlinear cascade/stage into point in time $t = 0$ voltage surge of $U_{\text{вх}}$ transient processes in diagram (Fig. 114) are described by the nonlinear differential equation

$$C_0 \frac{dU_{\text{вкл}}}{dt} + g_{\text{вкл}} U_{\text{вкл}} = S U_{\text{вх}}$$

or

$$\frac{dU_{\text{вых}}}{dt} + \frac{g_{\text{нел}}}{C_0} U_{\text{вых}} = -\frac{SU_{\text{вх}}}{C_0}. \quad (\text{V-1})$$

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In order to obtain the amplitude characteristic of cascade/stage, necessary for providing a strictly successive work of cascade/stages in n-cascade amplifier, equivalent conductivity of $g_{\text{нел}} = f(z)$ according to expressions (II-56), (II-59) and (II-61) must take the form

$$g_{\text{нел}} = g_0 \varphi(z), \quad (\text{V-2})$$

where the function $\varphi(z)$ it is determined by the expression

$$\varphi(z) = \begin{cases} 1 & \text{при } z \leq 1; \\ \frac{e^{-1}}{z} & \text{при } 1 \leq z \leq a \ln D_1 + 1; \\ \frac{D_1}{az} (z - a \ln D_1 - 1 + a) & \text{при } z \geq a \ln D_1 + 1. \end{cases} \quad (\text{V-3})$$

$$\text{Conductivity of } g_0 = g_a + g_{\text{вмх}} + g_{\text{вх}} = \frac{1}{R_0}.$$

After substitution into the equation (V-1) of the conductivity of the $g_{\text{нел}}$ of relative time of α_n and relative voltages x and z , we obtain

$$\frac{dz}{d\alpha_n} + \varphi(z) z = x(\alpha_n), \quad (\text{V-4})$$

where

$$\alpha_n = \frac{t}{C_0 R_0}. \quad (\text{V-5})$$

Under the influence of unit function, the variables in equation (V-4) are separate/liberated

$$\alpha = \int \frac{dz}{x(z) - \varphi(z)z} + C. \quad (V-6)$$

The result of the computation of integral (V-6) taking into account the initial conditions for the different sections of the amplitude characteristic of nonlinear cascade/stage takes the form:

for a linear section ($z \leq 1$)

$$\alpha_1 = \ln \frac{x}{x-z}; \quad (V-7)$$

for a logarithmic section ($1 \leq z \leq a \ln D_1 + 1$)

$$\alpha_{II} = \frac{z-1}{x} + \ln \frac{x}{x-1} + \frac{a}{x} \ln \frac{x-1}{z-1}; \quad (V-8)$$

for a quasi-linear section ($z \geq a \ln D_1 + 1$)

$$\alpha_{III} = \ln \frac{x}{x-1} + \frac{a}{x} \ln \frac{D_1(x-1)}{x-D_1} + \frac{a}{D_1} \ln \frac{\frac{x}{D_1} - 1}{\frac{x}{D_1} + \frac{a \ln D_1 + 1 - a}{a} - \frac{z}{a}}. \quad (V-9)$$

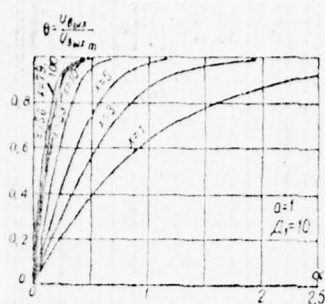


Fig. 115. The transient responses of nonlinear cascade/stage.

The transient responses of nonlinear cascade/stage in work in the logarithmic and quasi-linear mode/conditions of

$\eta = \frac{U_{max}}{U_{max_{yct}}} = f(\alpha_n)$ for case of $a = 1$, calculated from formulas (V-7), (V-8) and (V-9), are depicted on Fig. 115.

During the performance calculation, is taken most probable diapazn the LAX of cascade/stage $D_1 = 10$. Transient responses for the quasi-linear operating mode of cascade/stage are designed with $x = 10$; 33; 56; 79 and 102, which corresponds to relative entry stresses of the 1st, the 2nd, the 3rd, the 4th and 5th nonlinear cascade/stages at the end of the logarithmic range of five-stage amplifier. From the figure one can see that in an increase in the input time signal of the establishment of t_y and delay time in the t_3 of momentum/impulse/pulse at the output/yield of nonlinear cascade/stage sharply decrease. By set-up time, is understood the pulse rise-time from 0.1 to 0.9 its maximum values. The Vrmeya of delay corresponds to the pulse rise-time from 0 to 0.5 its maximum values. Figure 116 depicts the curves of a relative change in the set-up time of $\eta(x) = \frac{t_{y_{x=1}}}{t_{y_{x=100}}}$ and delay time in the $\chi(x) = \frac{t_{3_{x=1}}}{t_{3_{x=100}}}$ for $a = 1$ and $a = 0.434$.

In this case of $t_{y_{x=1}}$ and $t_{3_{x=1}}$ respectively set-up time and the time lag of momentum/impulse/pulse at the output/yield of the nonlinear cascade/stage when it works in linear conditions.

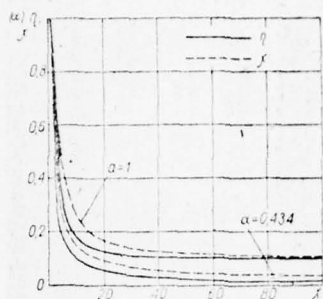
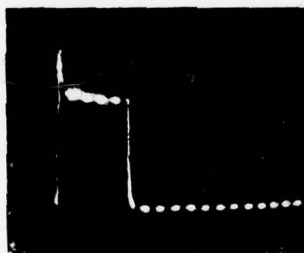


Fig. 116. Curves of a relative change in the delay time and set-up time of nonlinear cascade/stage.

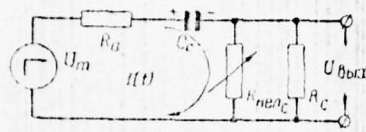
Fig. 117. Oscillogram of voltage pulse on the output/yield of nonlinear cascade/stage with the input voltage of $U_{BX} = 1V$



From the figure one can see that the maximum rate of change in the t_y and t_s is observed during a change in the input voltage in the range, equal to the range of the LAX of cascade/stage ($1 \leq x \leq D_1$). During a decrease in coefficient of a , which corresponds to an increase in the foundation of logarithmic operation N , the relative change in the t_y and t_s grow/rises. If we as nonlinear cell/elements apply germanium semiconductor detectors of the type of DG-Q, D2 and D9, then momentum/impulse/pulse at the output/yield of nonlinear cascade/stage with entry stress more than 0.1 in has characteristic peak at flat/plane apex/vertex. Figure 117 depicts the oscillogram of momentum/impulse/pulse the duration of $t_n = 3 \mu s$ at the output/yield of nonlinear cascade/stage with the input voltage of $U_{bx} = 1V$ (duration of the gauging marker of $t_k = 0,5 \mu s$). The value of peak depends on the value of input signal and grow/rises with an increase of the latter. In the work of nonlinear cascade/stage in logarithmic mode/conditions, the peak is not observed. It appears approximately in the middle of the quasi-linear section of the amplitude characteristic of the third nonlinear cascade/stage. In three-stage amplifier with logarithmic range 60 dB, the peak appears in the middle of range and toward the end of it can achieve 30-40% of the value of momentum/impulse/pulse. The duration of peak does not exceed 0.3-0.4 μs .

During the amplification of momentum/impulse/pulses by the duration of $t_n > 0,5 \mu s$ the peak does not affect the amplitude characteristic of amplifier.

Fig. 118. Equivalent diagram of nonlinear cascade/stage for the range of lowest frequencies.



During the amplification of the momentum/impulse/pulses of the short duration when $t_n \leq 0.5 \mu s$, the amplitude characteristic of amplifier strongly differs from calculated logarithmic. The appearance of a peak in momentum/impulse/pulse at the output/yield of nonlinear cascade/stage is caused by the inertness of semiconductor diode. If as the nonlinear cell/element, which shunts the plate load of amplifier stage, is used a germanium diode of the type of DG-S1DG-S4 or vakuumnyy diode, peak in momentum/impulse/pulse at the output/yield of nonlinear cascade/stage is absent with any input voltage. This indicates the fact that germanium semiconductor diodes of the type of DG-S1, DG-S2, DG-S3, DG-S4, DG-P3, DG-P4 and vacuum-tube diodes possess lesser inertness in comparison with diodes of the type of DG-Q1 - DG-Q10.

Thus, for the elimination of peak it is necessary to apply the nonlinear cell/elements, which have rapid response. Transient processes in the quite nonlinear cell/element, caused by finite time of the hole dislocation and electrons in semiconductor, dlzhny to last not the more hundredths of microsecond. These requirements satisfy germanium semiconductor diodes of the type of DG-S1 - DG-S4 and of DG-P3 - DG-P4.

Distortion of plane vershinye momentum/impulse/pulse.

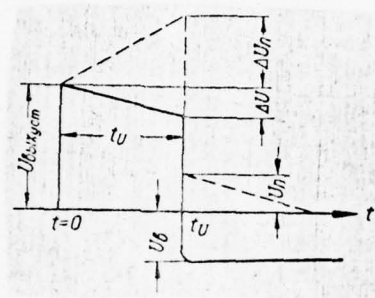
Formation/education of parasitic reverse/inverse overshoot.

As has already been spoken above, the distortions of flat/plane pulse apex are caused by the network elements, which determine the

frequency characteristic of nonlinear cascade/stage in the range of lowest frequencies. The equivalent diagram of nonlinear cascade/stage for lowest frequencies is depicted on Fig. 118.

For the most probable values of the anode resistor/resistance of the $R_a \geq 1$ of comas, transient capacitance/capacity of $C_c \geq 0,05$ μF and of pulse duration, the $t_n \leq (5 \div 10) \mu\text{s}$, when is fulfilled the inequality of $R_a C_c \gg t_n$, current $i(t)$, that takes place through the nonlinear cell/element, during the action of momentum/impulse/pulse, remains virtually constant.

Fig. 119. Distortions of momentum/impulse/pulse, caused by the transient capacitance/capacity of C_c .



Consequently, the resistor/resistance of the $R_{\text{нелс}}$ of nonlinear cell/element for this value of the quantity of voltage pulse also is constant.

Therefore the diagram, depicted on Fig. 118, during the action of momentum/impulse/pulse with a sufficient degree of accuracy can be considered as linear. In this case, one must take into account that to each value of input voltage corresponds its value of the resistor/resistance of $R_{\text{нелс}}$.

The value, which most completely characterizes transient processes during the action of momentum/impulse/pulse, is the relative decay in the flat/plane pulse apex, the numerically equal to the ratio of absolute decay in the flat/plane apex/vertex ΔU toward the end of the action of momentum/impulse/pulse to the maximum conservative value of momentum/impulse/pulse (Fig. 119)

$$\Delta = \frac{\Delta U}{U_{\text{выхуст}}}. \quad (\text{V-10})$$

Since the cascade/stage during the action of momentum/impulse/pulse is linear, the relative decay toward the end of the action of momentum/impulse/pulse, which is formed because of the charge of the transient capacitance/capacity of C_c according to [31] is equal to

$$\Delta_c = \frac{t_n}{C_c(R_{\text{нелс}} + R_a)}, \quad (\text{V-11})$$

where the t_n - pulse duration.

Expression (V-11) is correct during the execution of the inequalities of $C_c(R_a + R_{\text{ne}n_c}) \gg t_n$ and $R_c \gg R_{\text{ne}n_c}$. Taking into account the soprotivlniya of the escape of R_c expression (V-11) can be recorded

$$\Delta_c = \frac{t_n}{C_c \left(\frac{R_{\text{ne}n_c} R_c}{R_{\text{ne}n_c} + R_c} + R_a \right)}. \quad (\text{V-11a})$$

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After substituting into this equation of expression for an $R_{\text{ne}n_c}$ [formula (II-60) and (II-62)], in the work of kada in different mode/conditions we will obtain:

in work in linear conditions ($0 \leq x \leq 1$)

$$\Delta_{cI} = \frac{t_n}{C_c(R_a + R_c)}; \quad (\text{V-12})$$

in work in logarithmic mode/conditions ($1 \leq x \leq D_1$)

$$\Delta_{cII} = \frac{t_n (x - a \ln x - 1)}{C_c R_a x}; \quad (\text{V-13})$$

in work in quasi-linear mode/conditions ($x \geq D_1$)

$$\Delta_{cIII} = \frac{t_n \left(x - a \ln D_1 - 1 - a \frac{x}{D_1} + a \right)}{C_c R_a x}. \quad (\text{V-14})$$

Relative decay in the flat/plane pulse apex, which are formed because of the capacitance/capacity of C_k the connected to the

cathode circuit, capacitance/capacity of the anode filter of C_ϕ and capacitance/capacity in the circuit of the screen grid of C_s , the same as for a linear cascade/stage. According to [18, 31] these relative decay are determined by the following expressions:

otnositel'ny the decay, which is formed during the discharge of the capacitance/capacity of the C_K ,

$$\Delta_K = \frac{S_K t_n}{C_K}, \quad (V-15)$$

where the S_K - the slope/transconductance of amplifier tube on cathode current;

the relative decay, which is formed during the discharge of the capacitance/capacity of the C_ϕ ,

$$\Delta_\phi = \frac{t_n}{R_a C_\phi}; \quad (V-16)$$

the relative decay, which is formed during the discharge of the capacitance/capacity of the C_s ,

$$\Delta_s = \frac{t_n}{\frac{R_s R_{i_s}}{R_s + R_{i_s}} C_s}, \quad (V-17)$$

where the R_{i_s} is anode resistance on screen grid;

R_s - the resistor/resistance, connected in the circuit of screen grid.

Are common/general/total γ relative decay in the flat/plane pulse apex at the output/yield of the nonlinear cascade/stage

$$\Delta = \Delta_c + \Delta_k + \Delta_s - \Delta_\phi. \quad (V-18)$$

During an increase in the input voltage, the component Δ_c rapidly grow/rises and many times exceeds remaining component sums (V-18). Therefore during the calculation of relative decay at the output of n-cascade logarithmic amplifier for the nonlinear cascade/stage, assembled by diagram in Fig. 118, without considerable error it is possible to accept

$$\Delta \approx \Delta_c. \quad (V-19)$$

After the break-down of momentum/impulse/pulse, capacitance/capacity C_0 is discharged through two parallel-connected resistor/resistances of R_s and R_{nen} . Transient processes to the prirazyade of capacitance/capacity C_0 are described by nonlinear differential equation (V-1). In view of the fact that the form of decay in the momentum/impulse/pulse does not have vital importance, the author does not give the detailed analysis of transient processes during the discharge of capacitance/capacity C_0 . It should be noted that as a result of an increase in the resistor/resistance of R_{nen} the process of the discharge of capacitance/capacity C_0 the decay momentum/impulse/pulse is somewhat stretched in comparison with pulse edge. KA showed the theoretical and experimental studies, carried out by the author, the decay time in the momentum/impulse/pulse with $x \gg$

D, 2-3 times more set-up time.

The value, which most completely characterizes transient processes in nonlinear cascade/stage after the break-down of momentum/impulse/pulse, is the relative overshoot, numerically equal to the ratio of the voltage of the overshoot of U_n to the maximum value of the momentum/impulse/pulse

$$d = \frac{U_n}{U_{\text{выс}}}. \quad (\text{V-20})$$

Common/general/total relative overshoot is composed of the separate components, caused by the capacitance/capacities of the of the C_c, C_k, C_ϕ and C_s , $d = d_c + d_k + d_s - d_\phi$. (V-21) Constituting d_n, d_s and d_ϕ are such as for a linear cascade/stage, and they are determined respectively from formulas (V-15), (V-16) and (V-17). Special attention deserves the relative reverse/inverse overshoot, caused by the discharge of the capacitance/capacity of C_c after the break-down of momentum/impulse/pulse.

Fig. 120. Equivalent diagram of the discharge of the capacitance/capacity of C_c with the shunting of the plate load of cascade/stage by nonlinear cell/element.

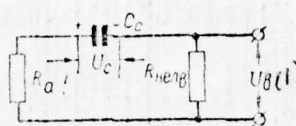


Figure 120 depicts the equivalent diagram of the discharge of the capacitance/capacity of C_c . In the diagram of $R_{\text{нел}}$ is marked the resistor/resistance of the nonlinear cell/element on which vydeyaetsya the voltage of the parasitic reverse/inverse overshoot of U_n . It is analogous [31] the relative overshoot, caused by the discharge of the capacitance/capacity of the C_c ,

$$d_c = \frac{t_n}{C_c(R_n + R_{\text{нел}})} \cdot \frac{R_{\text{нел}}}{R_{\text{нел}}}. \quad (\text{V-22})$$

Under the relative overshoot of d_c we will understand its maximum value at the moment the discharge of the capacitance/capacity of C_c .

During the execution of the inequality of the

$U_n \leq U_{\text{нел}} = K_1 U_{\text{нел}}$ (this inequality virtually is fulfilled always with $1 \leq x \leq 102$) of $R_{\text{нел}} \approx R_c \gg R_n$, since on the nonlinear cell/elements, which have the very high resistor/resistance, given the cutoff voltage of $E_{\text{нел}} = U_{\text{нел}}$. Then

$$d_c = \frac{t_n}{R_{\text{нел}} C_c}. \quad (\text{V-23})$$

After substituting into this equation of the value of $R_{\text{нел}}$ in the work of cascade/stage in different mode/conditions we will obtain:

in work in the linear conditions

$$d_{cl} = \frac{t_n}{C_c(R_n + R_c)}; \quad (\text{V-24})$$

in work in the logarithmic mode/conditions

$$d_{cII} = \frac{t_n (x - a \ln x - 1)}{C_c R_a (a \ln x + 1)}; \quad (V-25)$$

in work in the quasi-linear mode/conditions

$$d_{cIII} = \frac{t_n \left(x - a \ln D_1 - 1 - a \frac{x}{D_1} + a \right)}{C_c R_a \left(a \ln D_1 + 1 + a \frac{x}{D_1} - a \right)}. \quad (V-26)$$

With an increase in the input voltage (increase x) the relative overshoot of d_c sharply grow/rises and many times exceeds other component sums (V-8).

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Therefore during the calculation of relative overshoot at the output of n -cascade logarithmic amplifier without large error it is possible to accept

$$d = d_c. \quad (V-27)$$

For a generality it is expedient to introduce new values β and γ , that characterize a change in the Δ_c and d_c , but not depending on the cell/elements of the nonlinear cascade/stage C_c and of R_a and pulse duration of the t_n :

$$\beta = \Delta_c \frac{C_c R_a}{t_n}; \quad (V-28)$$

$$\gamma = d_c \frac{C_c R_a}{t_n}. \quad (V-29)$$

After substituting the values of Δ_c and d_c into expressions (V-28) and (V-29), in the work of cascade/stage in different mode/conditions we will obtain:

in work in the linear conditions

$$\beta_I = \gamma_I = \frac{1}{1 + \frac{R_c}{R_a}}; \quad (V-30)$$

in work in the logarithmic mode/conditions

$$\beta_{II} = \frac{x - a \ln x - 1}{x}, \quad (V-31)$$

$$\gamma_{II} = \frac{x - a \ln x - 1}{a \ln x + 1}; \quad (V-32)$$

in work in the quasi-linear mode/conditions

$$\beta_{III} = \frac{x - a \ln D_1 - 1 - a \frac{x}{D_1} + a}{x}, \quad (V-33)$$

$$\gamma_{III} = \frac{x - a \ln D_1 - 1 - a \frac{x}{D_1} + a}{a \ln D_1 + 1 + a \frac{x}{D_1} - a}. \quad (V-34)$$

Figure 121 depicts curves $\beta(x)$ and $\gamma(x)$ for $a = 1$ and $a = 0.434$. During the calculation of curves, the range the LAX of nonlinear cascade/stage is accepted $D_1 = 10$.

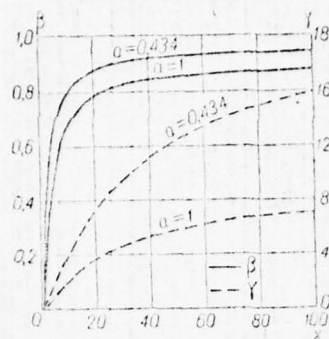


Fig. 121. Curves $\beta(x)$ and $\gamma(x)$ with the shunting of the plate load of cascade/stage by nonlinear cell/element.

These curves are suitable for nonlinear cascade/stages with any values of the resistor/resistance of R_a and capacitance/capacity of

C_c and for any pulse duration of t_n . Through curves we find that for the real diagram of nonlinear cascade/stage, depicted on Fig. 52, (with the $R_a = 0; R_a = 1,1$ of comas; $C_c = 0,1$ μF ;

$\frac{R_a}{R_c} = 0,01; t_n = 1$ μs) toward the end of the logarithmic range $D_1 =$

10 with $a = 1 \Delta_{cII} = 0,6\%$ and $d_{cII} = 1,8\%$; with $a = 0.434$

$\Delta_{cII} = 0,72\%$ and $d_{cII} = 3,6\%$. To the end/lead of the

quasi-linear section of the amplitude characteristic of the fifth nonlinear cascade/stage ($x = 102$) of n-cascade video amplifier we find

that with $a = 1 \Delta_{cIII} = 0,80\%$ and $d_{cIII} = 3,5\%$; with $a = 0.434$

$\Delta_{cIII} = 0,82\%$ and $d_{cIII} = 14,5\%$. For a linear cascade/stage

with the same cell/elements of R_a and C_c we have an

$\Delta_{c_{лин}} = d_{c_{лин}} = 0,01\%$.

In the cascade/stage of the amplification of the video pulses with of $t_n = 1$ μs without special work it is possible to obtain

$\Delta_{\phi} = d_{\phi} = 0,02\%$ and $\Delta_s = \Delta_K = d_s = d_K = 0,01\%$

(these values are obtained, if cascade/stage has the following

elementy: $R_a = 2$ ~~кОм~~ ^{MF}; $C_K = 90$ ~~пФ~~ ^{MF}; $C_{\phi} = 5$ ~~пФ~~ ^{MF}; $C_s = 0,3$ ~~пФ~~ ^{MF}; $R_{ts} = 33$ ~~кОм~~ ^{MF};

$S = 9$ mA/V).

Component Δ_{ϕ} and d_{ϕ} , having negative sign, compensate for component Δ_s, Δ_K, d_s and the d_K of sums (V-18) and (V-21). Therefore expression (V-19 (and (V-27) they yalvyayutsya by completely valid.

Comparing the given data, we see that in nonlinear cascade/stage on sravnenyu with linear relative decay in the flat/plane pulse apex

can increase ten times, and relative vybros- hundred times. It is natural that this sharp increase in the parasitic reverse/inverse overshoots in separate nonlinear cascade/stages leads to a sharp increase in the reverse/inverse vybross at output/yield n-cascade logarithmic video amplifier.

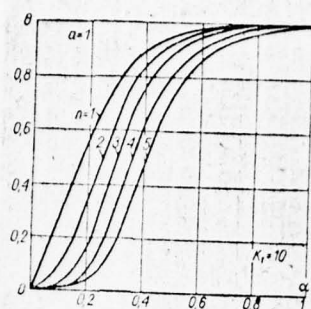


Fig. 122. The transient responses of multistage logarithmic video amplifier.

Table 1

n	1	2	3	4	5
$\xi = \frac{t_{\text{улог}}}{t_{\text{удин}}}$	0,077	0,119	0,097	0,084	0,0835
$\delta = \frac{t_{\text{элог}}}{t_{\text{эдин}}}$	0,24	0,154	0,117	0,098	0,09

Multistage amplifier. Distortions of pulse edge.

The differential equation, which describes transient processes at the output/yield of the i velineynogo cascade/stage of n -cascade video amplifier at the moment of the action of momentum/impulse/pulse, can be recorded in the following form:

$$\frac{dz_i}{d\alpha_b} + \varphi(z_i) z_i = D_1 z_{i-1}(\alpha_b), \quad (V-35)$$

where the z_{i-1} are a relative output potential ($i - 1$) of nonlinear cascade/stage.

Figure 122 depicts the calculated transient responses for the different number of nonlinear cascade/stages with $a = 1$ and $D_1 = 10$. The performance calculation is produced grafchnalitcheski according to equation (V-35). In any n the solution produced for the end/lead of the logarithmic range of n -cascade amplifier, which corresponds to relative entry stress of the first cascade/stage $x = D_1$. By comparing the transient responses, given in Fig. 122, with the characteristics of n -cascade linear amplifier, given in work [18], let us compose the Table of 1 relative change in the $t_{y, \text{лог}}$ and $t_{z, \text{лог}}$ of amplifier with the input voltage, which corresponds to the end/lead of the logarithmic range in comparison with of $t_{y, \text{лин}}$ and $t_{z, \text{лин}}$ when amplifier it amplifies low signals it works in linear conditions. Relative values are designated by the $\xi = \frac{t_{y, \text{лог}}}{t_{y, \text{лин}}}$ and the

$$\eta = \frac{t_{z, \text{лог}}}{t_{z, \text{лин}}}.$$

From table it is evident that with $n > 5$ values of δ and ϵ remain virtually constants.

Relative decay in the pulse apex and relative overshoot.

Relative decay in the flat/plane pulse apex at the output/yield of the n -cascade logarithmic video amplifier

$$\Delta_0 = \sum_{i=1}^{i=n} \Delta_{i\text{BLX}}, \quad (\text{V-36})$$

where the $\Delta_{i\text{BLX}}$ is component of common/general/total relative decay at the output/yield of video amplifier, caused by the decay, which are formed in the i nonlinear cascade/stage.

Formula (V-36) is accurate during the fulfillment of the inequality of $\Delta_{i\text{BLX}} \leq (10 \div 15) \%$.

Relative decay in the $\Delta_{i\text{BLX}}$ has different expressions in the work of nonlinear cascade/stages in different mode/conditions. In an example of the first cascade we find the expressions for $\Delta_{i\text{BLX}}$ during operation of cascades in linear conditions (this is related to all nonlinear cascade/stages, except the latter that must compulsorily work either in logarithmic or in kvazilaineynom mode/ccnditions). By finding the expression of $\Delta_{i\text{BLX}}$ for the first cascade/stage, let us suppose that one of the nonlinear cascade/stages (indifferently which) onshchzatel'no works in logarithmic mode/ccnditions, otherwise video amplifier will not have a LAX.

Utilizing a formula (I-17), is expressed output potential of n-cascade logarithmic video amplifier into points in time $t = 0$ and the $t = t_n$ by the output voltage of the first nonlinear cascade/stage:

$$U_{\text{BMX}}_{t=0} = K_1^n U_{\text{BXH}} \left(a \ln \frac{U_{\text{BMX}}(1)}{K_1 U_{\text{BXH}}} + 1 \right), \quad (\text{V-37})$$

$$U_{\text{BMX}}_{t=t_n} = K_1^n U_{\text{BXH}} \left[a \ln \frac{U_{\text{BMX}}(1)(1-\Delta_1)}{K_1 U_{\text{BXH}}} + 1 \right]. \quad (\text{V-38})$$

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In expression (V-38) the value of Δ_1 is relative decay in the nonlinear cascade/stage in work in linear conditions. According to equality (V-19) without large error it is possible to accept

$$\Delta_1 = \Delta_{c1}.$$

Relative decay at the output of the amplifier of Δ_{BMX} , caused by decay in the first nonlinear cascade/stage,

$$\Delta_{\text{BMX}} = \frac{U_{\text{BMX}}_{t=0} - U_{\text{BMX}}_{t=t_n}}{U_{\text{BMX}}_{t=0}}. \quad (\text{V-39})$$

After substituting expressions (V-37) and (V-38) into equation (V-39), we will obtain

$$\Delta_{\text{BMX}} = \frac{a \ln \frac{1}{1-\Delta_1}}{a \ln X + 1}, \quad (\text{V-40})$$

where X - the relative input voltage of amplifier.

Analogous expressions are obtained for all nonlinear

cascade/stages, which work in linear conditions. Therefore it is possible to record, that

$$\Delta_{i_{\text{BWX}}} = \frac{a \ln \frac{1}{1-\Delta_i}}{a \ln X + 1}. \quad (\text{V-40a})$$

This expression in n-cascade logarithmic video amplifier is correct for the i cascade/stage in the range of the relative voltages of the amplifier of $1 \leq X \leq D_1^{n-1}$.

For the last/latter nonlinear cascade/stage

$$\Delta_{n_{\text{BWX}}} = \Delta_i. \quad (\text{V-41})$$

If $\Delta_i \leq 5\%$, expression (V-40a) assumes the form

$$\Delta_{i_{\text{BWX}}} = \frac{a \Delta_i}{a \ln X + 1}. \quad (\text{V-42})$$

In the work of cascade/stages in logarithmic and quasi-linear modes, the absolute value of an increment (decrease) in the tension of ΔU_i on the output/yield of the i cascade/stage transmits to the output of n-cascade logarithmic amplifier without change, i.e.,

$$\Delta U_{i_{\text{BWX}}} = \Delta U_i = U_{\text{BWX}(i)} \Delta_{i_{\text{BWX}}},$$

where the $U_{\text{BWX}(i)}$ - output potential of the i nonlinear cascade/stage. Taking into account that the $\Delta_{i_{\text{BWX}}} = \frac{\Delta U_i}{U_{\text{BWX}}}$, expression for an $\Delta_{i_{\text{BWX}}}$ in the work of cascade/stages in logarithmic mode/conditions assumes the form

$$\Delta_{i_{\text{BWX}}} = \frac{\left(a \ln \frac{\lambda}{E^{n-1}} + 1 \right) \Delta_{i_{\text{BWX}}}}{a \ln X + 1}. \quad (\text{V-43})$$

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This expression is correct for the i cascade/stage in n -cascade logarithmic video amplifier in the range of the relative stresses of $D_1^{n-i} \leq X \leq D_1^{n-i+1}$.

Analogous expression for an $\Delta_{i \max}$ is obtained in the work of nonlinear cascade/stages in the quasi-linear mode/conditions

$$\Delta_{i \max} = \frac{\left(a \ln \frac{X}{D_1^{n-i}} + 1\right) \Delta_{iii}}{a \ln X + 1}. \quad (V-44)$$

Expression (V-44) is correct for the i nonlinear cascade/stage in the range of the relative stresses of $D_1^{n-i} \leq X \leq D_1^n$. According to equality (V-19) in expressions (V-43) and (V-44) it is possible to accept

$$\Delta_{ii, iii} = \Delta_{eii, iii}.$$

For the last/latter nonlinear cascade/stage

$$\Delta_{n \max} = \Delta_{ii, iii}. \quad (V-45)$$

If we into expressions (V-40a), (V-41), (V-43), (V-44) and (V-45) instead of Δ_1 the Δ_{11} and the Δ_{111} substitute values β_1 , β_{11} and β_{111} , we will obtain the new values

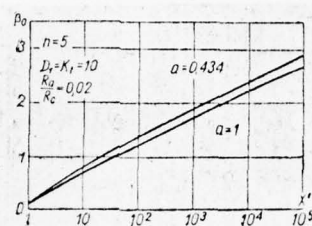
$$\beta_{i_{\text{BLX}}} = \Delta_{i_{\text{BLX}}} \frac{C_c R_a}{t_u},$$

the characteristic $\Delta_{i_{\text{BLX}}}$ and not depending on the cell/elements of the nonlinear cascade/stages of C_c and R_a and pulse duration of t_u . In this case, for a n-cascade amplifier, we have

$$\beta_0 = \sum_{i=1}^{i=n} \beta_{i_{\text{BLX}}}. \quad (\text{V-46})$$

Figure 123 shows curved the curves of dependences $\beta_0(X)$ for a five-stage logarithmic video amplifier with $a = 1$ and $a = 0.434$.

During the calculation of curves, is accepted the most probable case $D_1 = K_1 = 10$. On curve, depicted on Fig. 123, it is possible to determine relative decay in the flat/plare pulse apex at the output/yield of the five-stage video amplifier, which logarithmizes according to the law of natural and common logarithm in the range $D = 100$ dB, any values of R_a, C_c, t_u and $\frac{R_a}{R_c} = 0.02$.

Fig. 123. Curves $\beta_0(x)$ for a five-stage logarithmic video amplifier.

Thus, for instance, for the end/lead of the logarithmic range of video amplifier ($X = 10^5$) with $a = 1$; the $R_a = 2$ of comas;

$C_c = 0,1 \mu F$ $t_n = 1 \mu s$ the relative decay

$$\Delta_0 = \beta_0 \frac{t_n}{R_a C_c} 100 = 1,35\%,$$

that 27 times are more relative decay in the linear five-stage amplifier with the same values of R_a, C_c, R_c and t_n .

Under the influence on the input of the n-cascade logarithmic video amplifier of ideal momentum/impulse/pulse without reverse/inverse overshoot, relative overshoot at the output of the amplifier

$$d_0 = \sum_{i=1}^{i=n} d_{i_{\text{BHX}}}, \quad (V-47)$$

where the $d_{i_{\text{BHX}}}$ is the is component common/general/total relative vyborsa at the output/yield of video amplifier, caused by the overshoot, which are formed in the i nonlinear cascade/stage.

Formula (V-47) is valid according to [18] during the fulfillment of the inequality of $d_{i_{\text{BHX}}} \leq (10-15) \text{ c/o}$.

The parasitic reverse/inverse overshoots, which are formed in nonlinear cascade/stages, many times are less than the signal. Therefore while signal is amplified according to logarithmic law, reverse/inverse overshoot are amplified according to linear law. This law causes a sharp increase in the terms of sum (V-47) during an increase in the signal at the input of video amplifier. From the

calculation it is evident that toward the end of the logarithmic range 60-80 dB during logarithmic operation according to the law of natural logarithm ($a = 1$) on the output/yield of the video amplifier of that consisting of nonlinear cascade/stages, the equivalent diagram kotrykh is depicted on Fig. 113, the relative overshoot with of $t_n = 1 \mu s$, of the $R_a = 2$ of comas and $C_c = 0,1 \mu F$ can increase to 30-60%.

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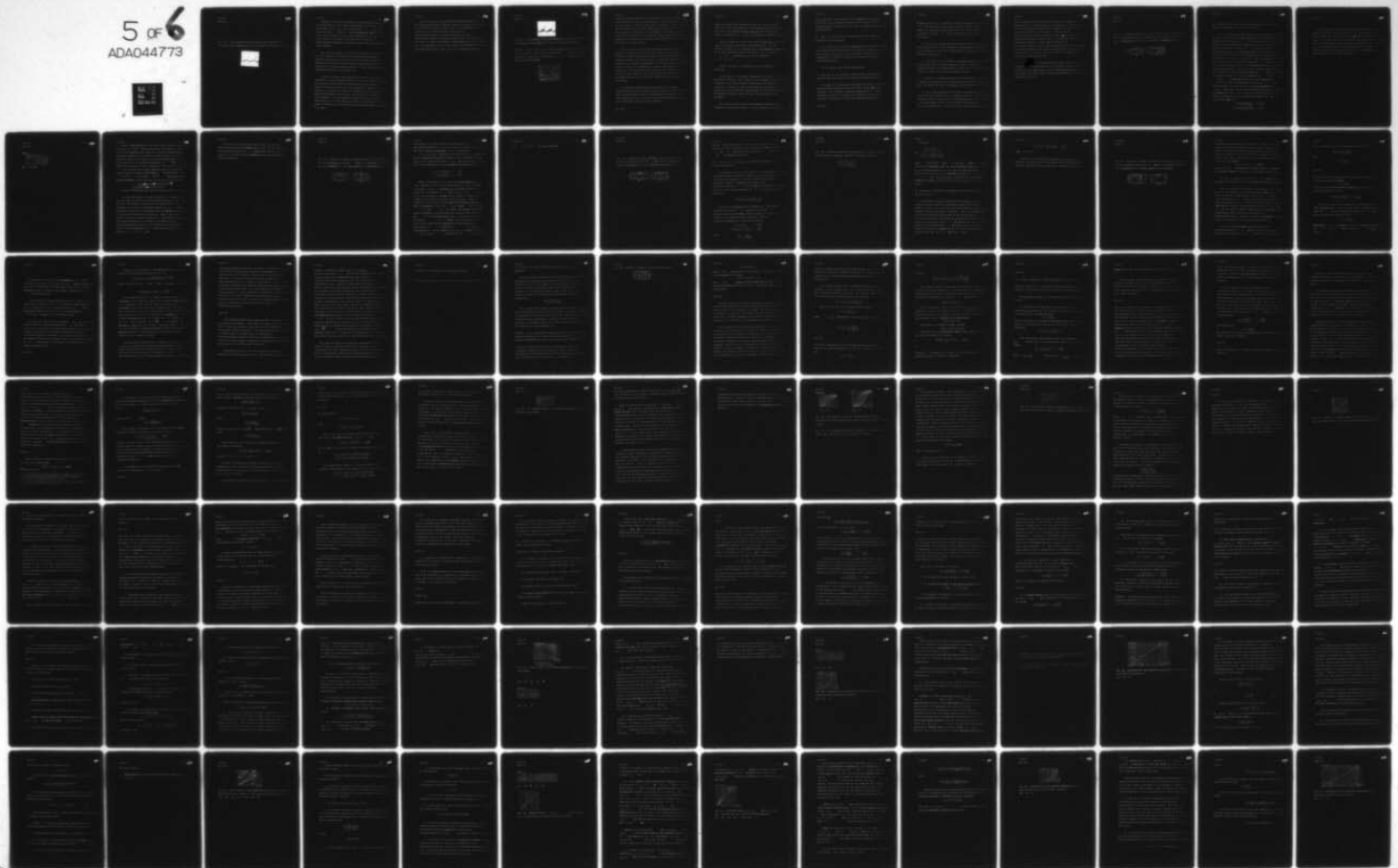
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Fig. 124. Oscillogram of voltage pulses on the output/yield of three-stage video amplifier at the end of the logarithmic range 60 dB.



Figure 124 shows the oscillogram of momentum/impulse/pulses at the output/yield of three-stage video amplifier at the end of the logarithmic range 60 dB. Pulse duration of $t_n = 5 \text{ } \mu\text{s}$, pulse repetition rate $F = 10000 \text{ Hz}$. Voltage pulses were supplied to the input of video amplifier from a pulse generator of the type of 26-I after limiter on the lower level which cut the parasitic reverse/inverse overshoots, available at those which are generated by pulse generator.

From ostsillogrammykh it is evident that after input process of the video amplifier of virtually ideal momentum/impulse/pulses (without reverse/inverse overshoots) reverse/inverse overshoot at the output/yield of video amplifier comprises approximately 70-75% of the value of the momentum/impulse/pulse of signal, which will agree sufficiently well with calculation data.

In order to observe the phenomenon of the loss of the maximum sensitivity by video amplifier during the action of powerful signals, on the input of video amplifier together with voltage pulses was supplied the noise voltage from noise generator. Instead of the noise voltage it is possible to supply the voltage of the high-frequency harmonic oscillations, which lie at the limits of the passband of video amplifier. If video amplifier during the action of powerful signals does not lose the maximum sensitivity, noise path/track at the output of amplifier has constant width from one momentum/impulse/pulse to the next.

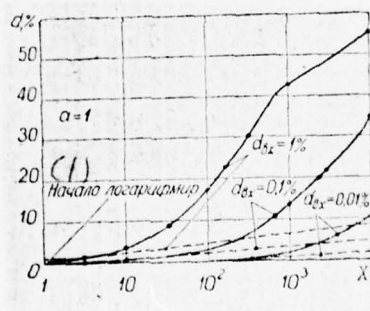
Figure 125 shows the oscillogram of momentum/impulse/pulses at the output/yield of video amplifier together with noise path/track at the end of the logarithmic range 60 dB. From oscillogram it is evident that the noise path/track directly after momentum/impulse/pulse is strongly narrowed, and then it rasshiyaetsya, nowhere remaining constant width. This indicates the fact that the maximum sensitivity of video amplifier does not manage to be restore/reduced for the time, equal to the repetition period of momentum/impulse/pulses, which leads to the following phenomena.

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Fig. 125. Oscillogram of momentum/impulse/pulses at the output/yield of logarithmic video amplifier together with noise path/track.

Fig. 126. Growth curve in the relative overshoot at the output/yield of the idela'nogo logarithmic video amplifier: ——— diagram without the suppression of overshoot; - - - - - diagram with the suppression of overshoot.



During the application/use of an indicator of the type "b" during the reverse/inverse overshoot of ekrantrubki, it will be darkened. If it is direct after the large signal, which corresponds to the end/lead of the logarithmic range of video amplifier 60 dB, will enter the low signal, which corresponds to the beginning of logarithmic range, then it will not increase screen brilliancy to value larger than screen brilliancy in the absence of signals, and it will turn out to be that which was not noted on screen.

With an indicator of the type "A" reverse/inverse overshoot deforms of signal and the line of pause, that it does not make it possible to accurately determine value and relationship/ratio of the signal, following each other through the small time interval. This phenomenon is especially inadmissible in the single-channel orienting systems in which very frequently are applied logarithmic video amplifiers. The low signals, which enter screen on completion of the action of large signals, on the scope of the type "A" are not also noticeable in view of the loss by the amplifier of the maximum sensitivity.

The property of logarithmic video amplifier to emphasize reverse/inverse overshoot develops itself when in the video amplifier itself are not formed parasitic reverse/inverse overshoots (ideal video amplifier), but to its input enter real momentum/impulse/pulses with insignificant reverse/inverse overshoot.

Figure 126 depicts the calculated growth curve in the relative overshoot on the output/yield of ideal logarithmic video amplifier from LAX in the range 80 dB after input process impulse with the relative overshoots of $d_{bx} = 0,01$; 0.1 and $10/c$ (unbroken curves).

From the figure one can see that with relative overshoot at the input of the ideal logarithmic video amplifier of $d_{bx} = 0,01\%$ relative overshoot at the output/yield of video amplifier toward the end of the logarithmic range 80 dB (with $a = 1$) it reaches the

$d_{bmx} = 10\%$; with of $d_{bx} = 0,1\% \rightarrow d_{bmx} = 32\%$ and with $d_{bx} = 1\% \rightarrow d_{bmx} = 54\%$.

During a decrease in coefficient of a , the values of grow/rise.

On the basis of the analysis conducted it is possible to make the following conclusion. For a decrease in the parasitic reverse/inverse overshoot at the output/yield of logarithmic video amplifier, it is necessary to decrease in every possible way the overshoots, which are formed both in the nonlinear cascade/stages of video amplifier and in the amplifier circuit, connected before the logarithmic video amplifier.

The considerable parasitic reverse/inverse overshoot is the fundamental reason, which limits the wide application of logarithmic

video amplifiers. The problem of the elimination of parasitic overshoots is the fundamental problem, with solution of which considerably will expand itself the field of application logarithmic vidcusiliteley.

§2. Ways of a decrease in the distortions of pulse signal in logarithmic video amplifier.

As a result of the conducted investigations the author determined some circuit solutions which make it possible to decrease the decay in the flat/plane pulse apex and the parasitic overshoot at the output/yield of nonlinear cascade/stage, caused by transient capacitance/capacity.

Let us examine each of them individually.

1. Correction of the flat/plane pulse apex and reverse/inverse overshoot with the aid of the corrective capacitance/capacity.

The decay in the flat/plane pulse apex, and also the parasitic reverse/inverse overshoot, which are formed during charge and discharge of the transient capacitance/capacity of C_0 can be partially or completely removed, by connecting in series with nonlinear cell/element the corrective capacitance/capacity.

As that correcting it is possible to utilize a capacitance/capacity of $C_{\delta n}$, the back-out resistor during which is created locking nonlinear cell/element voltage (see Fig. 33a). In this case the capacitance value of $C_{\delta n}$ must be the order of the tenths of microfarad.

On the basis of carried out by the author of the theoretical and experimental studies of the korektsii of reverse/inverse overshoot at the output/yield of nonlinear cascade/stage it is possible to make the following conclusions:

1. The value of the corrective capacitance/capacity depends both on the value and on the pulse duration of signal. Therefore the optimum correction of reverse/inverse overshoot can be obtained only for any one value and the pulse duration of signal.

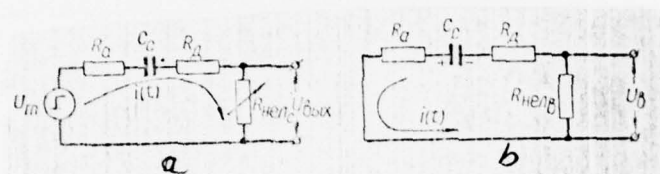
2. During the optimum correction of reverse/inverse overshoot, is observed considerable the perekorrektziya of flat/plane pulse apex, i.e., is observed the lift of flat/plane pulse apex (Fig. 119, prime).

3. It is most expedient the corrective capacitance/capacity to select from the condition of the optimum correction of reverse/inverse overshoot with the large signals, sotvetstvuyushchikh to the end/lead of the quasi-linear section of the amplitude characteristic of nonlinear cascade/stage. In this case with the average/mean signals,

which correspond to the logarithmic section of the amplitude characteristics of cascade/stage, it is observed the nedokorreksiya of the reverse/inverse overshoot which partially is corrected by the capacitance/capacity of anode filter. With low signals reverse/inverse overshoot completely is corrected in essence by the capacitance/capacity of anode filter. The resultant action of the capacitance/capacity of anode filter and corrective capacitance/capacity is such, that the overshoot at the output/yield of nonlinear cascade/stage in all requiring range of a change in the input voltage is much less than in the case of the absence of the corrective capacitance/capacity.

4. Correction of reverse/inverse overshoot with the aid of the corrective capacitance/capacity in the n-cascade video amplifier, intended for the amplification of the momentum/impulse/pulses, which are changed over a wide range in value and duration, does not give satisfactory results.

Fig. 127. Equivalent diagrams of charge (a) and of the discharge (b) of the capacitance/capacity of aaaaa with the shunting of the plate load of cascade/stage by 1st type nonlinear divider/denominator.



II. Shunting of the plate load of cascade/stage by the nonlinear divider/denominators of the 1st and 2nd tops.

If we consecutively with the nonlinear cell/element, which shunts the plate load of cascade/stage, include/connect the sufficiently high linear resistor/resistance of R_a (in this case is formed 1st type nonlinear divider/denominator), then the current of the charge of the transient capacitance/capacity of C_c during the action of momentum/impulse/pulse considerably decreases, which will lead to a decrease in the decay in the flat/plane pulse apex and parasitic reverse/inverse overshoot. Figure 127 depicts the equivalent diagrams of the charge of the capacitance/capacity of C_c during the action of momentum/impulse/pulse and its discharge after the break-down of momentum/impulse/pulse. By the indicated diagrams resistor/resistance R_0 is replaced by the resistor/resistance of R_a , since in the case of applying pentodes the resistor/resistance of $R_{BHX} \gg R_a$ and

$R_a \approx R_0$. During the fulfillment of the inequality of $t_n < C_c (R_a + R_d + R_{нелс})$ the capacitance/capacity of C_c charges itself according to linear law and the resistor/resistance of

$R_{нелс}$ during the action of momentum/impulse/pulse virtually does not change its value. In this case the transient decay and the relative overshoot, caused by capacitance/capacity the C_c , are respectively equal to:

$$\Delta_c = \frac{t_n}{C_c (R_a + R_d + R_{нелс})}; \quad (V-48)$$

$$d_c = \frac{t_n}{C_c (R_a + R_d + R_{нелс})} \cdot \frac{R_{нелн}}{R_{нелс}}. \quad (V-49)$$

From expressions (V-48) and (V-49) it is evident that with an increase in the resistor/resistance of R_n the relative values of decay and overshoot decrease, but increases the time constant of the circuit of the charge of the stray capacitance, which shunts the plate load of cascade/stage, that it leads to an increase in the set-up time of momentum/impulse/pulse at the output/yield of nonlinear cascade/stage during the amplification of the weak signals when cascade/stage works in linear conditions.

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Table 2.

$R_d^{(I)}$ (KOM)	0	0,5	10	50
ψ	1	0,67	0,1	0,02
ζ	1	0,62	0,07	0,006
γ	1	1,2	5,1	13

Key: (1) comas.

Table 2 gives calculation data, which show a relative decrease in the decay in $\psi = \frac{\Delta_c}{\Delta'_c}$ and reverse/inverse overshoot of $\zeta = \frac{d_c}{d'_c}$ at the output/yield of the last/latter nonlinear cascade/stage of five-stage amplifier in the work of cascade/stage in quasi-linear mode/conditions, and also data, that show relatively an increase in the set-up time of the momentum/impulse/pulse of $\frac{t_y}{t'_y} = \gamma$ in the work of cascade/stage in linear conditions. The values of ψ and ζ are designed for the quasi-linear section of the amplitude characteristic of cascade/stage (value of $d'_c = 6,5\%$; $\Delta'_c = 0,8\%$ and $t'_y = 0,75 \cdot 10^{-7}$ s correspond $R_a = 0$). The cell/elements and the parameters of cascade/stage are accepted by the following:

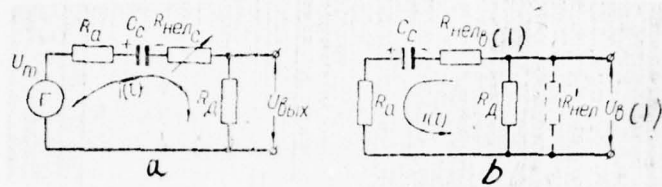
$$R_a = 1,1 \text{ k}\Omega; R_c = 100 \text{ k}\Omega; C_1 = C_{\text{max}} + \frac{C_M}{2} = 10 \text{ nF}; \\ C_2 = C_{\text{bx}} + \frac{C_M}{2} = 20 \text{ nF}; K_1 = D_1 = 10; a = 1.$$

During the calculation are used the curves, depicted on Fig. 24.

The sharp umen'shniye of decay and overshoot is caused by the fact that with an increase in the resistor/resistance of R_a for obtaining the necessary characteristic of cascade/stage it is necessary to increase the resistor/resistance of $R_{\text{нел.с.}}$. This is reached by switching on consecutively with the nonlinear cell/element of supplementary adjusting sprotivleniya. Table 2 shows that to decrease the reverse/inverse overshoot by a znachitelnym increase in the resistor/resistance of the aaaaaa of 1st type nonlinear divider/denominator possible in the logarithmic video amplifiers, intended for the amplification of momentum/impulse/pulses by the duration of $t_n > (1 \div 2) \text{ }\mu\text{s.}$

The decay in the flat/plane pulse apex and the parasitic reverse/inverse overshoot, caused by the charge and the discharge of the capacitance/capacity of C_0 considerably decrease with the shunting of the plate load of cascade/stage by 2nd type nonlinear divider/denominator.

Fig. 128. Equivalent diagrams of charge (a) and of the discharge (b) of the capacitance/capacity of C_c with the shunting of the plate load of cascade/stage by 2nd type nonlinear divider/denominator.



The equivalent diagrams of charge and discharge of the capacitance/capacity of C_c for the present instance are depicted on Fig. 128. During the fulfillment of the inequality of

$t_n \ll C_c (R_a + R_{\text{ne}\pi_c} + R_n)$ the capacitance/capacity of C_c during the action of momentum/impulse/pulse charges itself according to linear law and the resistor/resistance of $R_{\text{ne}\pi_c}$ virtually remains constant. Then relative decay and relative overshoot are respectively equal to:

$$\Delta_c = \frac{t_n}{C_c (R_a + R_{\text{ne}\pi_c} + R_n)}; \quad (\text{V-50})$$

$$d_c = \frac{t_n}{C_c (R_a + R_{\text{ne}\pi_b} + R)}; \quad (\text{V-51})$$

During an increase in the signal, the resistor/resistance of $R_{\text{ne}\pi_c}$ increases, and the resistor/resistance of $R_{\text{ne}\pi_b}$ virtually constantly in view of the smallness of the absolute value of the voltage of the overshoot of U_i and is equal $R_{\text{ne}\pi_c}$. This leads to the fact that with an increase in the signal the relative decay decreases, and relative overshoot remains constant. Thus, for instance, for the fourth cascade/stage of the diagram, depicted on Fig. 58 (paramety $K_1 = D_1 = 10$; $R_a = 30$ comas; $R_n = 1.2$ comas;

$C_c = 0.1 \mu\text{F}$; $R_{\text{ne}\pi_c} = 0.6$ comas), the relative decay and the relative overshoot, calculated from the formulas (V-50) and (V-52), when $t_n = 1 \mu\text{s}$ are respectively equal: for linear conditions of the work of

$\Delta_c \approx d_c = 0.030\%$; for the end/lead of the quasi-linear section of the amplitude characteristic of the

cascade/stage of $\Delta_c = 0.0070\%$ of $d_c = 0.030\%$.

Respectively for a linear cascade/stage with the network elements of

$R_a = 1.1$ comas; $R_c = 100$ comas and an $C_c = 0.1 \mu\text{F}$ when

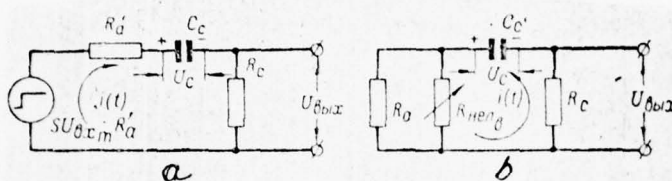
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of $t_u = 1 \mu s$ of $d_{c_{лин}} = \Delta_{c_{лин}} = 0.01\%$.

Fig. 129. Equivalent diagrams of charge (a) and of the discharge (b) of the capacitance/capacity of C_c upon the switching on of nonlinear cell/elements to the capacitance/capacity of C_c .



Thus, in cascade/stage with the plate load, shunted by 2nd type nonlinear divider/denominator, it is possible to obtain the values of Δ_c and d_c , comparable with the values of $\Delta_{c_{lin}}$ and $d_{c_{lin}}$ of linear cascade/stage.

III. Switching on of nonlinear cell/element to transient capacitance/capacity.

A considerable decrease in the decay in the flat/plane pulse apex and reverse/inverse overshoot is obtained upon the switching on of velineynykh cell/elements to transient capacitance/capacity. The equivalent diagrams of charge and discharge of the capacitance/capacity of C_c for the present instance are depicted on Fig. 129. The resistor/resistance of R'_a is determined from the expression

$$\frac{1}{R'_a} = \frac{1}{R_{\text{внх}}} + \frac{1}{R_a} + \frac{1}{R_{\text{внлс}}} \approx \frac{1}{R_a} + \frac{1}{R_{\text{внлс}}}.$$

During the fulfillment of the inequality of $(R_c + R'_a)C_c \gg t_n$ the capacitance/capacity of C_c during the action of momentum/impulse/pulse charges itself according to linear law. The relative decay and the relative overshoot, caused by capacitance/capacity, are respectively equal to:

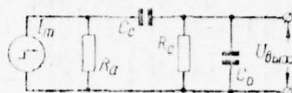
$$\Delta_c = \frac{t_n}{C_c(R'_a + R_c)}; \quad (\text{V-52})$$

$$d_c = \frac{t_n}{C_c(R'_a + R_c)} \cdot \frac{R_c}{R'_{\text{внлс}} + R_c}, \quad (\text{V-53})$$

where

$$R'_{\text{внлс}} = \frac{R_a R_{\text{внлс}}}{R_a + R_{\text{внлс}}}.$$

Fig. 130. Equivalent diagram of cascade/stage on anode circuit upon the inclusion of nonlinear elementov into cathode circuit.



Relations

$$\frac{\Delta_c}{\Delta_{c_{\text{min}}}} = \frac{R_a + R_c}{R'_a + R_c} \approx 1$$

and

$$\frac{d_c}{d_{c_{\text{min}}}} = \frac{(R_a + R_c) R_c}{(R'_a + R_c)(R_{\text{непн}} + R_c)} \approx 1,$$

since $R_c \gg R'_a$, $R_c \gg R_a$ and $R_c \gg R_{\text{непн}} \approx R_a$. Thus, the relative decay in the flat/plane pulse apex and the relative overshoot, caused by the capacitance/capacity of C_c upon the switching on of nonlinear cell/elements to the capacitance/capacity of C_c and with

$R_c \gg R'_a$ are virtually equal to relative decay and relative overshoot of linear cascade/stage and do not depend on the value of signal.

IV. Inclusion of nonlinear cell/element into the cathode circuit of amplifier stage.

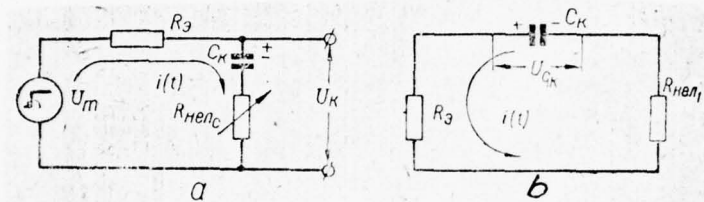
The equivalent diagram of nonlinear cascade/stage on anode circuit upon the inclusion of nonlinear element into katoduyu circuit is shown in Fig. 130, where all cell/elements are linear, and equivalent current generator is nonlinear. Under the influence on the input of the nonlinear cascade/stage of the voltage surge of U_{nx} the form of the jump of the current of equivalent generator does not repeat the form of the jump of U_{nx} and depends on the value of the impedance of the feedback of z_p , which they will be determined by transient processes in cathode circuit it is the function, which depends on the value of U_{nx} and time t . Thus,

$$I_m = S_o (U_{bx} - \frac{SU_{bx}}{1 + Sz_p}) = f(U_{bx}, t), \quad (V-54)$$

since $z_p = \psi(U_{bx}, t)$.

Because of this transient processes in the anode circuit of nonlinear cascade/stage can be described by the fairly complicated nonlinear differential equation whose solution is difficult.

Fig. 131. Equivalent diagrams of charge (a) and of the discharge (b) of the capacitance/capacity of C_K upon the inclusion of nonlinear cell/elements into the cathode circuit of cascade/stage.



If nonlinear cascade/stage is carried out on pentode, then the transient processes, which take place in cathode circuit, do not depend on transient processes in anode circuit. In this case transient processes in anode circuit can be examined as result of effect on the linear cascade/stage of the operating between grid and cathode of tube voltage

$$U_{c, k}(t) = U_{bx} - U_k(t), \quad (V.55)$$

where the $U_k(t)$ - voltage in the cathode circuit of nonlinear cascade/stage under the influence of the voltage surge of U_{bx} .

The law of a change in the stress of $U_k(t)$ can be found, by analyzing transient processes in the cathode circuit of cascade/stage.

Upon the inclusion of nonlinear cell/element into the cathode circuit of cascade/stage by the alternating/variable terms of sums (V-18) and (V-21) are the relative decay in the Δ_k and the relative overshoot of d_k , caused the charge and the discharge of the capacitance/capacity of C_k , which it divides nonlinear element on direct cathode current. For determining the values of Δ_k and d_k let us examine in general terms transient processes in cathode circuit during action and after the break-down of momentum/impulse/pulse. Figure 131 depicts the equivalent diagrams of charge and discharge of the capacitance/capacity of C_k .

During the action of momentum/impulse/pulse, the capacitance/capacity of C_k charges itself, then causes an increase in the tension of U_k . Increment of tension toward the

end of the action of the momentum/impulse/pulse of the t_n

$$\Delta U'_K = \frac{R_s}{R_s + R_{\text{нелс}}} \cdot \frac{1}{C_K} \int_0^{t_n} i dt,$$

where

$$R_s = \frac{R_{0,c}}{1 + SR_{0,c}}.$$

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This increment of the tension in katde produces a decrease in the voltage of signal in the anode

$$\Delta U_K = \Delta U'_K SR_0.$$

In this case, the relative decay, caused by the charge of the capacitance/capacity of the C_K ,

$$\Delta_K = \frac{\Delta U_K}{U_{\text{вх}} S_{\text{гт}}} = \frac{\Delta U'_K (1 + S\rho)}{U_{\text{вх}}}. \quad (\text{V-56})$$

During an increase in the signal, the resistor/resistance of $R_{\text{нелс}}$ increases, which causes the fulfillment of the inequality of $C_K (R_s + R_{\text{нелс}}) \gg t_n$, and the capacitance/capacity of C_K charges itself according to linear law. Then

$$\Delta U'_K = \frac{i_m t_n}{C_K} \cdot \frac{R_s}{R_s + R_{\text{нелс}}}.$$

Substituting $\Delta U'_K$ in equation (V-56) and taking into account that the $R_{0,c} \gg \frac{1}{S}$, $R_s \approx \frac{1}{S}$ and the current of $i_m = \frac{U_{\text{вх}}}{R_s + R_{\text{нелс}}}$, we obtain

In expression (V-57) enter two variables of $R_{\text{нел.}}$ and ρ , depending on the value of the signal of $U_{\text{вх.}}$. With an increase in the signal of znamenatal', increases much faster than the numerator. Therefore during an increase in the signal, relative decay in the Δ_k sharply decreases.

Carried out by the author precise analysis of transient processes showed that by expression (V-57) it is possible to pol'sovat'sya also with low signals, since the capacitance/capacity of C_k selects sufficiently large, order 30-50 pF, and the inequality of $C_k (R_g + R_{\text{нел.}}) \gg t_H$ virtually it is fulfilled always.

In view of the fact that the voltage of $U_{\text{с.к.}}$ of up to which charges itself the capacitance/capacity of C_k for the pulse action time, is very small even with large signals and does not exceed the units of milivol't, the resistor/resistance of nonlinear cell/element during the discharge of the capacitance/capacity of C_k is constant and equal to the minimum value of the resistor/resistance of $R_{\text{нел.}}$. Consequently, the discharge of capacitance/capacity occurs in linear network.

Analogichno it is possible to show that the relative overshoot, caused by the capacitance/capacity of the C_K ,

$$d_K = \frac{t_n}{C_K (R_g + R_{\text{нел}c})} \cdot \frac{R_{o,c} (1 + S_p)}{(R_{o,c} + R_{\text{нел}c} + S R_{\text{нел}1} R_{o,c})}. \quad (\text{V-58})$$

Taking into account that $R_g \approx \frac{1}{S}$ and $R_{o,c} \gg R_{\text{нел}1}$, we obtain

$$d_K = \frac{t_n S}{C_K (1 + S R_{\text{нел}1})} \cdot \frac{1 + S_p}{1 + S R_{\text{нел}c}}. \quad (\text{V-59})$$

From expression (V-59) it is evident that the value of d_K with an increase in the signal decreases, since the resistor/resistance of $R_{\text{нел}c}$ increases faster than the resistor/resistance of p . The calculation, carried out according to formulas (V-57) and (V-59), shows that toward the end of the quasi-linear section of the amplitude characteristic ($x = 102$) of the cascade/stage, assembled on the tube of 6J5P (with parameters $K_1 = D_1 = 10$; $a = 1$; $C_K = 30 \mu\text{F}$; the $R_{o,c} = 5,1$ of the komy of $R_{\text{нел}1} = 100 \frac{\mu\text{H}}{\text{cm}}$) the value of Δ_K decreases 13 times from $1.3 \cdot 10^{-2} \text{ o/o}$. Since the values of Δ_K and d_K are permennymi, common/general/total relative decay and the relative overshoot of the cascade/stage also of value variables decrease with an increase of signal.

Reverse/inverse overshoots can be removed, if we from the diagram of nonlinear cascade/stage exclude capacitance/capacities and to fulfill cascade/stage by the amplifier circuit of direct current. This amplifier is idel'nym from the viewpoint of the formation/education in it of reverse/inverse overshoots. Increasingly

previously examined methods make it possible to considerably decrease the parasitic reverse/inverse overshoot, obzouyushchiysya in the amplifier itself, and thereby to draw nearer it the idela'nomu amplifier. In this case the matter with the amplification of momentum/impulse/pulses to obstoti is satisfactory, if to the input of logarithmic amplifier enter idel'nye momentum/impulse/pulses without reverse/inverse overshoots. Thus, for instance, for providing a normal operation of ideal logarithmic video amplifier in dynamic range to 80 dB to the input of amplifier it is necessary to supply momentum/impulse/pulses with the parasitic reverse/inverse overshoot, which does not exceed 0.001-0.002o/o from the value of momentum/impulse/pulse.

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Real momentum/impulse/pulses always have more considerable reverse/inverse overshoot. This leads to the fact that at the output even of idela'nogo amplifier toward the end of the logarithmic range the overshoot sharply grow/rises. This deficiency/lack it is possible to largely remove in diagrams with 1st type nonlinear divider/denominator and with nonlinear by cell/elements in the cathode circuits of cascade/stages, including the supplementary semiconductor diodes, which cut reverse/inverse overshoots.

Supplementary diodes in the first diagram are included in parallel to resistor/resistance R_6 etc. (see Fig. 58), in the second

diagram - in parallel to plate load to the transient capacitance/capacity of C_0 . In this case network elements must be designed taking into account the which shunts effect of depletion layer diodes on load. In the presence of supplementary diodes, parasitic reverse/inverse overshoots are amplified with lesser amplification factor, than signal. Let us agree this amplifier to call logarithmic video amplifier with the suppression of reverse/inverse overshoot. The best results of the suppression of reverse/inverse overshoot are obtained in diagram with nonlinear cell/elements in the cathode circuits of cascade/stages. Figure 126 by primes shows growth curve in the relative overshoot at the output/yield of four-stage logarithmic video amplifier with the suppression of reverse/inverse overshoot during the amplification of real momentum/impulse/pulses with the relative overshoots of

$d_{BX} = 1; 0.1 \text{ and } 0.01$ c/o. The Principal diagram of this nonlinear cascade/stage is depicted on Fig. 57 (voltage by which begins the LAX of cascade/stage, during the calculation accepted of $U_{BX1} = 40 \text{ mV}$). Figure 126 shows that the reverse/inverse overshoot in the output of amplifier with suppression can be obtained approximately 10 times less than in ideal logarithmic video amplifier.

Thus, upon the inclusion of nonlinear cell/elements into the cathode circuits of amplifier stages it is possible to design ideosilitel' with wide logarithmic range or the order of 80-100 dB, which has the virtually instantaneous restoration/reduction of the maximum sensitivity after the action of short signals, which

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correspond to the end/lead of the logarithmic range.

§3. Method of the study of transient processes in selective amplifiers.

During the study of transient processes the amplifier resonance cascade/stage of logarithmic amplifier both in the case of the shunting of plate load by nonlinear cell/element and in the case of obtaining LAX by the consecutive addition of voltages, can be presented in the equivalent diagram, shown in Fig. 132. General equivalent nonlinear conductivity in the anode circuit of the cascade/stage

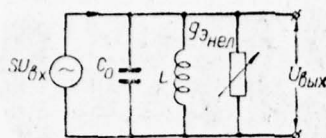
$$g_{\text{нел}} = g_{\text{вых}} + g_{\text{св}} + g_{\text{нел}} + g_{\text{вх}} \quad (\text{V-60})$$

For a diagram with separate detectors (see Fig. 95) in expression (V-60) nonlinear conductivity with low signals is the input admittance of detector, and with large signals - the input admittance of the tube of the following cascade/stage. During the study of transient processes in equivalent diagram (Fig. 132) is utilized the method of the slowly being changed amplitudes ¹.

FOOTNOTE 1. The possibility of applying a method of the slowly being changed amplitudes for the study of transient processes in selective logarithmic amplifiers is shown in work [16], etc. ENDFOOTNOTE.

In order to define the distortions of radio pulse, caused by logarithmic amplifier, it is necessary to study the transient responses both one cascade/stage and the mnogokraskadnogo amplifier with disconnection at point in time $t = 0$ voltage surge

Fig. 132. Equivalent diagram of resonance cascade/stage.



$$u_{bx}(t) = U_{bx}(t) \cos \omega t,$$

where $U_{bx}(t)$ is envelope of input voltage. Then output potential can be presented in the form

$$u_{bix}(t) = U_{bix}(t) \sin[\omega t - \psi(t)],$$

where $U_{bix}(t)$ - envelope of the output voltage, which is the slowly being changed function of time; $\psi(t)$ are the slowly being changed phase.

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Transient processes in selective amplifier stages with nonlinear load are described by the nonlinear differential equations whose degree depends on the complexity of diagram. The routine methods of the solution to nonlinear differential equations in mathematics do not exist, which extremely complicates the solution potavlennoy problem and forces to be turned k to the approximation methods of integration.

Since during the study of transient processes is of interest only envelope of oscillations, i.e., the law of a change in the amplitude of oscillations at the output of amplifier, it is most expedient to investigate transient processes by obtaining the approximate differential equations for envelope (ukcrechennykh equations) with the subsequent solution by their graphoanalytical method. With this method of study, the problem is simplified, since which interest us envelope are obtained without the plotting of curves of high frequency and, furthermore, the shortened equations for envelope they are the

nonlinear differential equations of lower order, than the initial differential equations of transient process. The graphoanalytical solution to the obtained ukorechennykh equations presents no difficulties.

The detailed procedure for the composition of the shortened equations is given in work [11]. Let us compose shortened equation for the diagram, depicted on Fig. 132. Let us record expression for the composite factor of amplification of the diagram

$$K(j\omega) = SZ(j\omega) = \frac{j\omega LS}{(j\omega)^2 LC + j\omega Lg_{\text{нел}} + 1}.$$

Taking into account that equivalent circuit damping

$$\delta_g = \frac{g_{\text{нел}}}{\omega_0 C_0} = \omega_0 L g_{\text{нел}},$$

where $\omega_0 = \frac{1}{\sqrt{LC}}$ — the resonance frequency of duct, we obtain

$$K(j\omega) = \frac{S}{g_{\text{нел}}} \cdot \frac{j \frac{\omega}{\omega_0} \delta_g}{\left(\frac{j\omega}{\omega_0}\right)^2 + \frac{j\omega}{\omega_0} \delta_g + 1}.$$

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Let us find expression for the shortened composite amplification factor of the small detuning when $\omega = \omega_0 + \Delta\omega$. Taking into account that

$$\frac{\omega}{\omega_0} = 1 + \frac{\Delta\omega}{\omega_0},$$

we obtain

$$K[j(\omega_0 + \Delta\omega)] = \frac{S}{g_{\text{нел}}} \cdot \frac{j\delta_s + j\frac{\Delta\omega}{\omega_0}\delta_s}{\left(\frac{j\Delta\omega}{\omega_0}\right)^2 + 2j\frac{j\Delta\omega}{\omega_0} + j\delta_s + j\frac{\Delta\omega}{\omega_0}\delta_s}.$$

The relative detuning of $\Delta\omega/\omega_0$ and the attenuation of δ_s are the small first-order quantities. By reject/throwing in numerator and denominator all terms of the second and higher than the orders of smallness and podtavlyaya the value of δ_s , we will obtain

$$K(j\Delta\omega) = \frac{S}{2j\Delta\omega C_0 + g_{\text{нел}}}.$$

There is virtually greatest interest in the case, when tuned amplifier is tuned to a frequency of signal. By taking into account this observation, it is possible to operate not with composite, but real envelope. Then is envelope at the output/yield

$$U_{\text{вмх}}(t) = K(j\Delta\omega) U_{\text{вх}}(t).$$

Substituting the value of $K(j\Delta\omega)$, we have

$$(2j\Delta\omega C_0 + g_{\text{нел}}) U_{\text{вмх}}(t) = S U_{\text{вх}}(t).$$

Considering $j\Delta\omega$ as differential operator $j\Delta\omega = d/dt$, we obtain the shortened equation for envelope

$$2C_0 \frac{dU_{\text{вмх}}}{dt} + g_{\text{нел}} U_{\text{вмх}} = S U_{\text{вх}}^*. \quad (\text{V-61})$$

1.

FOOTNOTE 1. In equation (V-61) under U one should understand the amplitude values of stresses. ENDFOOTNOTE.

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§4. Transient processes in tuned amplifier with single ducts.

Transient processes in a resonance logarithmic amplifier with nonlinear cell/elements in the anode circuits of cascade/stages.

The schematic diagram of the investigated amplifier is depicted on Fig. 78.

For obtaining the required amplitude characteristic of cascade/stage conductivity for a fundamental harmonic of anode current in equation (V-61) must take the form

$$g_{\text{neat}} = g_0 \varphi(z),$$

where the function $\varphi(z)$ just as in the case of logarithmic video amplifier is determined by expression (V-3), but the general conductivity

$$g_0 = g_{\text{max}} + g_{\text{ov}} + g_a = \frac{1}{R_0}.$$

After substituting into equation (V-61) the conductivity of g_{neat} , relative time α and the relative stresses x and z , we will obtain

$$\frac{dz}{d\alpha} + \varphi(z) z = x(\alpha), \quad (V-62)$$

where $\alpha = \frac{\delta_0 \omega_0}{2} = \frac{t}{2C_0 R_0}$ - relative time; $\delta_0 = \frac{1}{\omega_0 C_0 R_0}$ - circuit

damping in the work of cascade/stage in linear conditions when $z \ll 1$.

Equation (V-62) is analogous with the equation (V-4), which describes transient processes in logarithmic video amplifier. Therefore the solution to equation (V-62) for the different sections of the amplitude characteristic of cascade/stage are the expressions (V-7), (V-8) and (V-9).

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Transient responses and the curves of a relative change in the set-up time and delay time in the logarithmic cascade/stage of the amplification of video pulses, depicted on Fig. 115 and 116, and also the transient responses of multistage logarithmic video amplifier, given in Fig. 122, are accurate for a tuned amplifier during the corresponding replacement of relative time of α_0 by α . Comparing relative time of the video amplifier (aperiodic amplifier) of α_0 with relative time of tuned amplifier with single by ducts α , we see that during the execution of the equality of $\alpha_0 = \alpha$ the value of resistor/resistances R_0 in the anode circuits of the amplifier stages of video amplifier 2 times is more than in the cascade/stages of tuned amplifier (with identical capacitance/capacities in the anode circuits C_0). Consequently, in this case logarithmic video amplifier in work in linear conditions has a passband 2 times less, but the maximum amplification factor 2 times

larger than tuned amplifier. Distortions of pulse edge in both amplifiers identical. With the equality of ranges LAX absolute changes in the delay time of the signal of aaaa and set-up time of the momentum/impulse/pulse of t_y in this case in both amplifiers identical.

With the equality of stray capacitances C_0 and of resistor/resistances R_0 in the anode circuits of the cascade/stages of video amplifier and tuned amplifier, the maximum factors of amplification and band of the proipuskaniya of both amplifiers are identical. Then with the equality of ranges LAX relative changes of the time lag of signal $\Delta\alpha$ both in aperiodic and in tuned amplifier odikakcvye, but an absolute change in the delay time of the signal in the logarithmic video amplifier of Δt_{3b} 2 times are less than in resonance, since:

$$\Delta t_{3b} = \Delta\alpha R_0 C_0; \quad (V.63)$$

$$\Delta t_{3p} = \Delta\alpha 2R_0 C_0, \quad (V.64)$$

that with $\Delta\alpha_b = \Delta\alpha$

$$\Delta t_{3b} = 0,5\Delta t_{3p}.$$

This property of logarithmic amplifiers one should consider during the design of different equipment.

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Transient processes in a resonance logarithmic amplifier with separate detectors.

During the study of transient processes in amplifier with separate detectors (see Fig. 95) let us assume that the detectors are inertia-free and their transmission factors of k_d are equal to unity.

The equivalent diagram of the investigated cascade/stage is analogous to the diagram, depicted on Fig. 132, and for the search of the shape of the envelope of output voltage it is possible to utilize an equation (V-61). It should be noted that during the high load impedance of the detector of $(R_n \gg R_0)$ the nonlinearity of the conductivity of g_{neg} in essence is determined by the nonlinearity of the input admittance of the tube of the following cascade/stage and nonlinearity detector it is possible not to consider.

Equation (V-61) can be solved graphically or analytically. To graphically solve this equation is convenient, if there is a graphic representation of the law of a change of the conductivity of g_{neg} for a fundamental harmonic of anode current depending on the value of the amplitude of stress. During graphical solution it is possible to consider a change in the slope/transconductance of the tube of the investigated cascade/stage on the high levels of input voltage. For this, in the right side of the equation (V-61) one should substitute the value of the amplitude of the fundamental harmonic of the anode current of the $I_{m_1} = S U_{\text{ax}}$, found analytically or graphically according to the anode-grid characteristic of tube for this value of

input voltage. To consider the dependence of the slope/transconductance of tube on input voltage is especially important during the study of transient processes in the multistage amplifier when cascade/stages work with overloading. The law of a change in the $g_{\text{нел}}$ from the amplitude of applied voltage can be calculated as follows. Knowing the value of the common/general/total anadnogo resistor/resistance R_0 , having the grid characteristic of tube for the assigned operating mode and the volt-ampere characteristic of detector (taking into account the load impedance of $R_{\text{н}}$), we construct the common volt-ampere characteristic of nonlinear load. Then analytically, if there is an approximation of common volt-ampere characteristic, or graphically by the method five crdinates (see Fig. 87) we design the dependence of the fundamental harmonic of the current of $I_{\text{нел}}$ on the amplitude of the applied voltage of $I_{\text{нел}} = f(U)$, and then from formula (II-100) we design the dependence of $g_{\text{нел}} = f(U)$.

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During analytical solution equation (V-61) it is expedient to record in the following form:

$$2C_0 \frac{dU_{\text{вых}}}{dt} + I_{\text{нел}} = SU_{\text{вх}}, \quad (\text{V-65})$$

where $I_{\text{нел}} = g_{\text{нел}} U_{\text{вых}}$.

The solution to equation, similar to equation (V-65), with different approximations of dependence $i_{\text{нел}} = f(U)$ is given in S. N. Krinz's doctoral dissertation, "Transient Processes in Linear and nonlinear aperiodic circuits."

For solving equation (V-65) it is necessary the dependence of $I_{\text{нел}} = f(U)$ to approximate by an function.

1. Approximation by the exponential function of $I_{\text{нел}} = I_0 e^{aU}$.
 This approximation is permissible in the stochastic load impedance of the detector of R_n . Then equation (V-65) it is possible to record

$$2C_0 \frac{dU_{\text{внх}}}{dt} + I_0 e^{aU_{\text{внх}}} = I_m,$$

where $I_m = SU_{\text{внх}}$,

whence

$$\frac{t}{2C_0} = \int \frac{dU_{\text{внх}}}{I_m - I_0 e^{aU_{\text{внх}}}} + N.$$

This integral is undertaken by the substitution of $y = I_0 e^{aU_{\text{внх}}}$.
 Finally the solution to equation (V-65) takes the form

$$U_{\text{внх}} = \frac{1}{a} \ln \frac{1}{\left(1 - \frac{I_0}{I_m}\right) e^{-\frac{a I_m t}{2C_0}} + \frac{I_0}{I_m}}. \quad (\text{V-66})$$

Envelope of output voltage can be calculated from expression (V-66), by being given the separate concrete/specific/actual values of time t . In this expression it is possible to consider the nonlinearity of the tube of the investigated cascade/stage, by substituting the appropriate value of I_m , which considers a change in the slope/transconductance.

2. Approximation by the exponential function of $I_{\text{нел}} = \frac{U^n}{R_0}$.
 This case of approximation is most probable.

Here R_0 , the total resistance of the plate load of cascade/stage in work in linear conditions. Equation (V-61) can be recorded

$$2C_0 \frac{dU_{\text{BLX}}}{dt} + \frac{U_{\text{BLX}}^n}{R_0} = I_m.$$

Introducing relative time $\alpha = t/2C_0R_0$, we have

$$\frac{dU_{\text{BLX}}}{d\alpha} + U_{\text{BLX}}^n = I_m R_0,$$

whence

$$d\alpha = \int \frac{dU_{\text{BLX}}}{I_m R_0 - U_{\text{BLX}}^n}.$$

Taking into account that $I_m = \frac{U_{\text{ycr}}^n}{R_0}$, and substituting $\theta = \frac{U_{\text{BLX}}}{U_{\text{ycr}}}$, we obtain

$$\alpha = U_{\text{ycr}}^{1-n} \int \frac{d\theta}{1 - \theta^n} + K.$$

The integrand of the integral of $N = \int \frac{d\theta}{1 - \theta^n}$ is a special case of the binomial differential

$$N = \int \frac{d\theta}{1 - \theta^n} = \int \theta^m (d + b\theta^n)^p d\theta, \quad (\text{V-67})$$

in which $m = 0$; $d = 1$; $b = 1$ and $p = -1$.

According to Chebyshev's, theorem the integral of binomial differential in the final form can be expressed through elementary functions only in three cases: 1) p is integer; 2) $m + 1/n$ - integer; 3) $p + m + 1/n$ - integer.

In our case is satisfied the first condition ($p = -1$). Therefore

integral (V-67) can be found in the final form with all whole and any fractional rational number n . At the whole values the integral (V-67) is tabular.

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For example with $n = 1$

$$N = \int \frac{d\theta}{1-\theta} = -\ln(1-\theta);$$

with $n = 2$

$$N = \int \frac{d\theta}{1-\theta^2} = \frac{1}{2} \ln \frac{1-\theta}{1+\theta} = \text{Arth } \theta.$$

With n fractional and rational number integral (V-67) is undertaken by the substitution of $y = 1 - \theta^n$. Then

$$N = \int \frac{d\theta}{1-\theta^n} = - \int \frac{(1-y)^{\frac{1}{n}-1}}{ny} dy. \quad (\text{V-68})$$

For an example let us find the value of the integral (V-67) with $n = 1/4$

$$\begin{aligned} N &= -4 \int \frac{(1-y)^3}{y} dy = -4 \int \frac{1-3y+3y^2-y^3}{y} dy = \\ &= 2 \left[\frac{11}{3} - 2\theta^{\frac{1}{4}} - \theta^{\frac{1}{2}} - \frac{2}{3} \theta^{\frac{3}{4}} - 2 \ln(1-\theta^{\frac{1}{4}}) \right]. \end{aligned}$$

For incommensurate values of n integral (V-67) it can be calculated approximately by the expansion of integrand in the series

$$\begin{aligned} N &= \int \frac{d\theta}{1-\theta^n} = \int (1-\theta^n)^{-1} d\theta = \int (1 + \theta^n + \theta^{2n} + \dots) d\theta = \\ &= \theta + \frac{\theta^{n+1}}{n+1} + \frac{\theta^{n+2}}{n+2} + \dots + \frac{\theta^{n+k+1}}{n+k+1}. \quad (\text{V-69}) \end{aligned}$$

By utilizing d' Alembert's sign/criterion, it is possible to demonstrate that with $\theta < 1$ series (V-69) converges.

By solving equation (V-61) analytically, it is possible to investigate transient processes only in single cascade/stage under the influence on the input of voltage surge. By solving equation (V-61) graphically, it is possible to investigate transient processes in multistage amplifier by substituting in the right side of the equation the function of $I_m(t)$, which depends on time. In both cases the equation (V-61) is solved for a concrete/specific/actual amplifier circuit.

Figure 133 depicts perekhodye characteristics for one cascade/stage, assembled on a tube of the type of 6J1P. By the load of cascade/stage is the single oscillatory circuit, shunted the input impedance of a tube of the type of the 6J1P of the following cascade/stage and detector of the type of D2J with the load impedance of the $R_n = 2,8 \text{ KOM}$. Parameters of the investigated cascade/stage: $\Delta F_1 = 3.8 \text{ MHz}$; $f_0 = 30 \text{ MHz}$; $K_1 = 10$. The dependence of the entry impedance of the $R_{\text{ex},1} = f(U)$ of the tube of 6J1P on the value of the amplitude of input voltage is designed according to the grid characteristic, depicted on Fig. 49, for the following operating mode of the tube: $U_a = U_g = 120 \text{ v}$; $E_{\text{cm}} = -1,5 \text{ v}$.

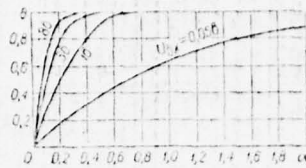


Fig. 133. The transient responses of resonance cascade/stage with different input voltage.

The Zavisimostvkhodnogo resistor/resistance of detector $R_{bx_d} = f(U)$ from the value of input voltage is designed according to the procedure, presented in works [9] and [10].

After the calculation of dependence of $R_{bx_d} = f(U)$ and the $R_{bx_d} = f(U)$ were refined experimentally by substitution method. Figure 133 shows that the time lag and the set-up time of momentum/impulse/pulse at the output/yield of cascade/stage sharply decreases with an increase in the signal, which indicates the powerful shunting of the load of cascade/stage by the entry impedance of the following tube. Carried out by the author of investigation showed that at the values of the load impedance of the detector of $R_u \geq (2 \div 3) R_0$ by the effect of the entry impedance of detector it is possible to disregard. The complete overloading of the investigated cascade/stage began with input voltage 8 in, in this case output voltage - also order 8 in.

A sharp decrease in the delay time in cascade/stage with an increase of signal especially is perceptible in multistage amplifier. The transient responses of the six-stage logarifimicheskogo amplifier, assembled on the tubes of 6J1P and which has the parameters; $f_0 = 30$ MHz; $K_0 = 10\%$; $\Delta F = 1$ MHz, are depicted on Fig. 134 and 135. The characteristics, given in Fig. 134, correspond to the case when to the input of the last/latter cascade/stage enters voltage yelichinoy 1 in, i.e., when all cascade/stages they work in linear conditions. In order that the last/latter cascade/stage would work in identical conditions with the other, its plate load was shunted by the

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supplementary nonlinear cell/element, replacing the input of the following tube. Because of this its transient response corresponds to the characteristic, depicted from Fig. 133 in $U_{ix} = 1$ a. We will consider that this case corresponds to the beginning of the LAX of amplifier.

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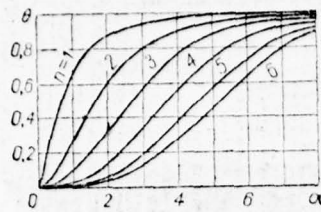


Fig. 134.

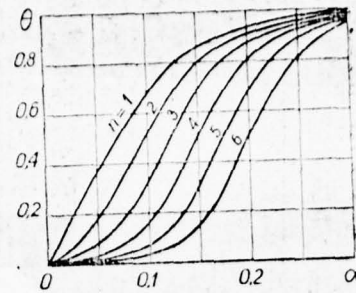


Fig. 135.

Fig. 134. The transient responses of amplifier with separate detectors on of input signal level, which corresponds to the beginning of LAX.

Fig. 135. The transient responses of amplifier on of input signal level, which corresponds to the end/lead of the IAX.

The transient responses, which correspond to the end/lead of the LAX of amplifier, when on the input of the first cascade/stage given voltage 8 into all cascade/stages are handled, depicted on Fig. 135. If delay line is designed out of the condition of providing a signal delay between cascade/stages for a period, accurately equal to the delay time of the signal in cascade/stage in work in linear conditions, i.e., out of condition (IV-26), then the delay time in the signal of amplifier on of input signal level, which correspond to beginning and the end/lead of the LAX of amplifier, sharply is distinguished. This is evident from Fig. 136, in which are shown the transient responses of the resulting video pulse on overall load for of input signal level, which correspond to the beginning of the LAX of amplifier (is curve 1) and to end/lead the LAX of amplifier (is curve 2). In this case, the delay line provides a delay in the videosignal between cascade/stages for a period

$$t_3 = t_{3. \kappa} = \frac{1}{\pi \Delta F_1} = 2C_0 R_0,$$

that it corresponds $\alpha = 1$.

In this case the delay time of the amplifier decreased 2 times. In a number of cases, in particular in logarithmic radar receivers, this change of the delay time in the signal is inadmissible.

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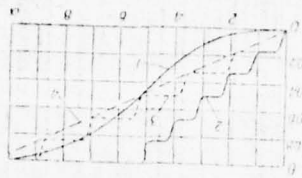


Fig. 136. The transient responses of amplifier on the resulting video pulse with the different levels of signal and different delay lines.

For providing a constancy of the delay time in the amplifier in all dynamic range of the LAX of liniyuzaderzhki it is necessary to design so, a toby it it provided a delay in the videosignal between cascade/stages for a period

$$t'_s = \frac{2(t_{s,n} - t')}{n}, \quad (V-70)$$

where $t_{s,n}$ - the delay time in the amplifier on signal level, corresponding to the beginning of LAX; t' - the delay time, determined on the transient response of the average cascade/stage on signal level, corresponding to the end/lead of the LAX of amplifier (in six-stage amplifier to average one should count the third cascade/stage, in semikaskadnom - the fourth); n is a number of amplifier stages.

The transient response of the amplifier of the resulting video pulse for the case when delay line is designed from condition (V-70), is depicted as prime (is curve 3) on Fig. 136. At the level 0.5 characteristics 1 and 3 have common point. It should be noted that these characteristics are constructed not allowing for the inertness of the load of detectors. If the time constant of the load circuit of detector is selected from the condition

$$\tau_d = C_d R_d = \frac{t'_s}{2} = \frac{t_{s,n} - t'}{n}, \quad (V-71)$$

that flanges on characteristic 3 they are smoothed and characteristics virtually it takes the form of straight line (is straight line 4). In this case the logarithmic amplifier has identical delay time on both of input signal level, which correspond to beginning toward the end of

the LAX.

On the basis of the analysis conducted it is possible to make the following conclusions. If the load of amplifier stage is a constant value and does not depend on signal level (diagram with anode and cathode detection when the input impedance of a tube during the sufficiently high resistor/resistance of aaaaaa can be considered high and constant), then delay line one should design, on the strength of condition (IV-26). If the load of amplifier stage is variable and depends on signal level (diagram with separate detectors), then delay line it is necessary to design, on the strength of condition (V-70), and the load circuit of detector - made of condition (V-71).

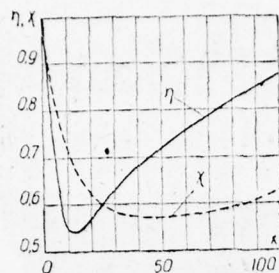


Fig. 137. Curves of a relative change in the set-up time and delay time in amplifier stage in 2nd type nonlinear divider/denominator.

§5. Ways of the stabilization of the delay time of the signal in logarithmic amplifiers.

The considerable dependence of the delay time in the signal on the level of the input voltage in a number of cases limits the application/use of logarithmic amplifiers. As a result of the conducted investigations, are outlined the following ways of the stabilization of delay time in logarithmic amplifiers.

1. Shunting of the plate load of cascade/stage by 2nd type nonlinear divider/denominator. In this case during an increase in the signal, the time constant of anode circuit grow/rises, which leads to a sharp increase in the set-up time of momentum/impulse/pulse in the anode circuit of cascade/stage. As a result of the logarithmic operation of signal by nonlinear divider/denominator the effect of the extension of pulse edge in anode circuit in lesser measure transmits to the output/yield of cascade/stage, i.e., to the output/yield of divider/denominator.

Figure 137 depicts the curves of a relative change in the delay time in γ and time of the ustanmovleniya of η at the output/yield of cascade/stage in the plate load, shunted by 2nd type nonlinear divider/denominator. Parameters of cascade/stage at work in the linear conditions: $K_1 = D_1 = 10$; $f_0 = 30$ MHz; $\Delta f_1 = 2.4$ MHz; the $R_a = 30$ KOM; $R_n = 2,2$ KOM; tube 6J1P.

From the figure one can see that the set-up time and delay time

during an increase in the signal first decreases, and then it increases.

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Especially considerably grow/rises the set-up time. It should be noted that upon the inclusion of oscillatory circuit into grid circuit in parallel to the resistor/resistance of the divider/denominator of R_n with an increase in the capacitance/capacity of duct (with a decrease in the passband of cascade/stage) a relative change in the times of t_s and t_y decreases, i.e., delay time is stabilized. This property can be utilized in narrow-band amplifiers. In mnokaskadnom logarithmic amplifier a decrease in the delay time in the first cascade/stages is compensated for by an increase in the delay time in the last/latter cascade/stages.

In five-stage logarithmic amplifier with 2nd type nonlinear divider/denominators (parameters of amplifier in the linear conditions: $f_0 = 30$ MHz; $\Delta f = 1$ MHz; $K_0 = 4 \cdot 10^5$) during a change of the signal in dynamic range to 80-90 dB the delay time in the signal decreases not more than by 30-40%.

2. Application/use of amplifiers with coupled circuits. I. Ya. Cramer showed that in amplifier stage with coupled circuits during the appropriate selection of the parameters of ducts it is possible to ensure the constancy of the delay time in the t_s during a change in

value of one of the resistor/resistances, shunting ducts. If changes resistor/resistance R_1 (see Fig. 81 in the absence of nonlinear cell/elements), that shunts the first duct, then the constancy of time of t_1 is reached of the relationship/ratio of the parameters

$$k_{ce} = \delta_2, \quad (V-72)$$

where k_{ce} - the coupling coefficient; $\delta_2 = \frac{1}{\omega_0 C_{02} R_{02}}$ - the attenuation of the secondary circuit;

$$\frac{1}{R_{02}} = \frac{1}{R_2} + \frac{1}{R_{0e2}} + \frac{1}{R_{BX}}.$$

If changes resistor/resistance R_2 , which shunts the secondary circuit, then the constancy of aaaa it is reached with the relationship/ratio

$$k_{ce} = \delta_1, \quad (V-73)$$

where $\delta_1 = 1/\omega_0 C_{01} R_{01}$ - the attenuation of the first duct;

$$\frac{1}{R_{01}} = \frac{1}{R_1} + \frac{1}{R_{BLX}} + \frac{1}{R_{0e1}}.$$

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During the fulfillment of relationship/ratics (V-72) and V-73) a cascade/stage it has the so-called optimum parameters. During a change of the value of resistor/resistance R_{02} 8 times (from $R_{02} = 0.25 R_{01}$ to $R_{02} = 2R_{01}$) the delay time of the signal in cascade/stage in the optimum parameters changes only by 37c/o. For a comparison it is possible to indicate that in cascade/stage with single duct under the same conditions time of t_1 changes 8 times.

Since cascade/stage from the LAX, in which one of the ducts is shunted by nonlinear resistance, is not identical to linear cascade/stage with the alternating/variable back-out resistor, the stabilization of delay time in it is obtained below than in linear cascade/stage. Transient processes in amplifier with coupled circuits also can be investigated, by utilizing a method of the slowly being changed amplitudes. The investigations, carried out by the author, they showed following:

during an increase in the relative tension $\times 10$ times the relative set-up time of the η of cascade/stage with the optimum parameters (with $K_1 = D_1$) decreases approximately 3 times, and the relative delay time of the $\times - 2$ times. During increase \times into 100, relative time of η decreases approximately 7 times, but time of $\times - 4$ times, i.e., in considerably lesser measure, than in the case of amplifier stage with single resonant circuit;

with an increase in the input voltage the overshoot on flat/plane pulse apex first grow/rises, and then decreases;

with an increase in the base of the logarithm, according to the law of which, it occurs the logarithmic operation of signal, overshoot by flat/plane pulse apex it grow/rises and it can achieve very great significance.

Thus, with wide to passband logarithmic amplifier with coupled circuits (optimum parameters) can give the higher stability of the delay time in the signal, than amplifier in the single ducts, shunted only by nonlinear cell/elements. During the execution of amplifiers on identical tubes, the first amplifier will have the lesser number of cascade/stages, than as the second. This fact causes the supplementary stabilization of time lag in amplifier with coupled circuits in comparison with amplifier on single ducts.

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3. Calculation of delay lines in amplifiers in the consecutive addition of the voltages in accordance with indications presented in §4 the present chapter.

Out of all examined methods the best stabilization of the delay time in the signal can be obtained by the appropriate selection of the delay time of the artificial lines in the amplifier in which the LAX is obtained by the addition of voltages.

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Chapter Six

Calculation, tuning and the adjustment of logarithmic amplifiers.

In the present chapter are given a procedure and examples for the calculation of some types of the logarithmicheskikh amplifiers, intended for concrete/specific/actual equipment/devices. The remaining types of logarithmic amplifiers can be calculated, by utilizing a material of the preceding/previous chapters of the book.

§1. Procedure for calculation of logarithmic amplifiers during a change in the amplification factor.

Calculation of resonance logarithmic amplifier.

Let us examine a procedure and an example of the calculation of n-cascade logarithmic UPCh of the receiver of radar station. For the calculation must be known the following performance data:

the minimum passband UPCh in work in linear conditions ΔF ;

the resonance intermediate frequency f_0 ;

the minimum voltage of signal on input UPCh of $U_{BX_{min}}$;

the minimum output potential UPCh (or at the input of detector), caused by noises, $U_{BY_{min}}$;

dynamic range LAX UPCh on input voltage D;

dynamic range LAX on the output voltage of D_{LAX} relative to the output voltage of the $U_{\text{LAX, min}}$ with which begins LAX UPCh, or the dynamic range h relative to the minimum output noise voltage of $U_{\text{ш, LAX, min}}$ (Fig. 140). If the LAX of amplifier begins from the level, which lies on 20 dB (10 times) lower than RMS value of amplifier noises that is the range

$$h = \frac{U_{\text{LAX, max}}}{U_{\text{ш, LAX, min}}} = \frac{na \ln D_1 + 1}{a \ln 10 + 1}. \quad (\text{VI-1})$$

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During the calculation of the logarithmic amplifier, intended for a computer, instead of the values of D_{LAX} and h can be assigned the base of logarithm N , according to the law of which must occur the logarithmic operation of signal.

The calculation of logarithmic tuned amplifier (UPCh) is produced in the following order.

1. Is selected the type of tube and diagram UPCh. Tubes and diagrams UPCh are selected from the same considerations, as during the calculation of linear UPCh. If it is required to obtain in logarithmic UPCh a smallest absolute change in the time lag of signal, then it is expedient to select tubes with a large slope/transconductance of the type of 6J9P, 6J11E, 6J20P, 6J21P and

6J22P.

2. We determine entry stress of the U_{BXH} , by which must begin the LAX UPCh. From chapter I, it is known that the fluctuations of interferences are pressed by logarithmic receiver to the inherent noise level in such a case, when LAX begins from the level, which lies on 20 dB lower than RMS value of noise voltage. By usually logarithmic is fulfilled by UPCh of receiver. Then the noise voltage of U_{mBX} on input UPCh one should undertake equal to the minimum voltage of the signal of the U_{BXMIN} , which corresponds to the ultimate sensitivity of receiver. In this case, the voltage

$$U_{BXH} = \frac{U_{UHX}}{10} = \frac{U_{BXMIN}}{10}. \quad (VI.2)$$

3. We determine the maximum factor of amplification UPCh K_0 of work in linear conditions. With the input voltage of $U_{BX} \leq U_{mBX}$ the minimum output potential UPCh is caused in essence by the shmami, RMS value of which at input UPCh on 20 dB is higher than the level on which begins the LAX.

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Therefore in the absence of the voltage of signal and effect at input UPCh only of noise voltage, operating point on the amplitude characteristic of the last/latter nonlinear cascade/stage is found somewhere at the end of the logarithmic section (in the case $D_1 = 20$ dB), and the factor of amplification of the last/latter nonlinear

cascade/stage

$$K_{(n)} = \frac{K_1 U_{BX_1}}{10 U_{BX_1}} \left(a \ln \frac{10 U_{BX_1}}{U_{BX_1}} + 1 \right) = \frac{K_1}{10} (a \ln 10 + 1),$$

i.e. it is decreased in m once where

$$m = \frac{K_1}{K_{(n)}} = \frac{10}{a \ln 10 + 1}. \quad (VI-3)$$

This decrease in the factor of amplification of the last/latter nonlinear cascade/stage must be accepted into consideration during the calculation of common/general/total maximum factor of amplification UPCh in the minimum output voltage. Then

$$K_0 = m \frac{U_{BX_{MHH}}}{U_{BX}}. \quad (VI-4)$$

Since in expression (VI-3) is unknown coefficient a , value m tentatively it is possible to undertake equal from 3 to 5, which corresponds to a change in coefficient of a from 1 to 0.434 or to a change in the foundation of logarithmic operation from 2.72 to 10. Virtually coefficient $a < 0.434$ almost never is undertaken. Then

$$K_0 = (3 \div 5) \frac{U_{BX_{MHH}}}{U_{BX}}. \quad (VI-4a)$$

4. We determine the maximum factor of amplification of one cascade/stage. First we determine the stable factor of amplification of one cascade/stage of $K_{1_{\text{ver}}}$. The maximum factor of amplification of cascade/stage K_1 is selected less than the stable coefficient by 20-30% in order that it was possible to routinely change it to the previous value K_1 and thereby to remove the distortions of the LAX of n -kasadnogo amplifier, caused by the ageing of tubes. Of this

selection K_1 , the maximum factor of amplification UPCh one should design without gain margin.

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To decrease the maximum factor of amplification of cascade/stage to the necessary value (in work in linear conditions) possible, selecting the appropriate operating mode of tube (supply of the secondary stress of displacement to the control electrode of tube, a decrease in the anode and screen voltages etc.) or join up of the cathode of tube the adjustable resistor of feedback. The second method of adjustment is more convenient in operation.

Thus, must be fulfilled the condition

$$K_1 = (0,7 \div 0,8) K_{\text{ver}}. \quad (\text{VI-5})$$

5. We determine the total resistance of plate load R_0 .

6. We determine the number of intermediate frequency stages

$$n = \frac{\ln K_0}{\ln K_1}. \quad (\text{VI-6})$$

7. We determine the passband of one cascade/stage ΔF_1 and the capacitance/capacity of duct C_0 .

8. Is selected the number of nonlinear cascade/stages, which can be equal the total to number of amplifier stages UPCh or less. With

an increase in the number of nonlinear cascade/stages, increases dynamic range UPCh on input voltage. When selecting the number of nonlinear cascade/stages, it is necessary to proceed from the following: UPCh must have the required range LAX; in all logarithmic range UPCh it must not be overloaded both of linear and nonlinear cascade/stages. If during the calculation it seems that the last/latter nonlinear cascade/stage at the end of the logarithmic range UPCh is overloaded, then it is expedient to decrease the values of the input voltage of U_{BX_1} and coefficient a , but the last/latter cascade/stage to execute linear in order to obtain at the input of detector the rated value of the minimum noise voltage of $U_{\text{ВМХ, мин}}$.

9. We determine coefficient a , which characterizes slope/inclination LAX UPCh. If is assigned dynamic range on output/yield UPCh relative to the voltage of $U_{\text{ВМХ}}$, then coefficient a is determined according to the formula

$$a = \frac{D_{\text{ВМХ}} - 1}{n \ln D_1}, \quad (\text{VI-7})$$

where n is a number of nonlinear cascade/stages.

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If is assigned dynamic range on output/yield UPCh relative to the voltage of $U_{\text{ВМХ, мин}}$, then coefficient a is determined according to the formula

$$a = \frac{h - 1}{n \ln D_1 - h \ln 10}, \quad (\text{VI-8})$$

10. We determine entry stress of the last/latter nonlinear cascade/stage of the U_{BX_1} by which it enters the logarithmic operating mode.

If in UPCh all cascade/stages are nonlinear, then the stress of U_{BX_1} we determine according to the formula

$$U_{BX_1} = U_{BX_H} K_I^{n-1}. \quad (VI-9)$$

If the last/latter intermediate frequency stage is linear, then the stress of U_{BX_1} we determine according to the formula

$$U_{BX_1} = U_{BX_H} K_I^{n-2}. \quad (VI-10)$$

11. We determine the entry stresses and on the output/yield of the last/latter nonlinear cascade/stage by which terminates the logarithmic section of its amplitude characteristic:

$$U_{BX_2} = U_{BX_1} K_1; \quad (VI-11)$$

$$U_{BHX_2} = K_1 U_{BX_1} (a \ln D_1 + 1). \quad (VI-12)$$

12. With output voltages from $U_{BHX_1} = K_1 U_{BX_1}$ to U_{BHX_2} for the last/latter nonlinear cascade/stage according to formulas (II-59) and (IV-11) (in the case of the shunting of plate load by nonlinear cell/elements) ¹.

FOOTNOTE ¹. The special feature/peculiarities of the calculation of logarithmic amplifiers upon the inclusion of nonlinear cell/elements into the cathode circuits of cascade/stages are examined below in an

example of the calculation of logarithmic video amplifier.
ENDFOOTNOTE.

For all remaining nonlinear cascade/stages this dependence we design from those formulas, after accepting coefficient of $a = 1$.

13. With output voltages from $U_{\text{out},i} = K_i U_{\text{BX},i} (a \ln D_i + 1)$ to the $U_{\text{out},i} = K_i U_{\text{BX},i} (a \ln D_i + 1)$, where i - the reference number of nonlinear cascade/stage, for the last/latter nonlinear cascade/stage according to formulas (II-61) and (IV-15) in the sluche of the shunting of plate load nonlinear by cell/elements we design and stroim the dependence of $R_{\text{нел},i} = f(U_{\text{нел},i})$.

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For remaining nonlinear cascade/stages this dependence we design also from formulas (II-61) and (IV-15) for output voltages from $U_{\text{out},i}$ to $U_{\text{out},i}$ after accepting coefficient of $a = 1$.

14. Is selected nonlinear cell/element in accordance with the requirements, presented in §5 chapter II.

15. For the different values of the cutoff voltage of $E_{\text{sat},\text{нел}}$ on nonlinear cell/element, we design and construct the family of curves of the dependence of the entry impedance of nonlinear cell/element on the applied to it sine voltage. Curved

$R_{\text{нелл, III}} = f(U_{\text{нелс}})$ and $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ must be constructed on one curve/graph.

16. If the curve of the required law of a change in the resistor/resistance of nonlinear cell/element coincides not with one of the curves of $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$, we produce fitting of one of them, nearest to curved $R_{\text{нелл, III}} = f(U_{\text{нелс}})$, increasing the number of nonlinear cell/elements, included in parallel, if curved $R_{\text{нелл, III}} = f(U_{\text{нелс}})$ lie/rests below selected curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$, or connecting in series with nonlinear cell/element supplementary effective resistance, if curved $R_{\text{нелл, III}} = f(U_{\text{нелс}})$ lie/rests above selected curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$.

17. From formulas (II-54) and (IV-1), utilizing a podognanuyu curved $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$, we design the amplitude characteristics of the latter and penultimate nonlinear cascade/stages. The characteristics of the nonlinear cascade/stages, which precede the last/latter nonlinear cascade/stage, are identical. In the case of $a = 1$, amplitude characteristics of all nonlinear cascade/stages are identical.

18 From the amplitude characteristics of nonlinear cascade/stages we design and construct amplitude characteristic UPCh. On this same curve/graph we construct a precise LAX UPCh, calculated from formula (I-17), and we determine the deviation of the calculated amplitude characteristic from accurately logarithmic.

19. Utilizing the transient responses of n-cascade logarithmic amplifier, given in chapter V, we design the maximum absolute change of the time lag of signal in logarithmic UPCh.

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Example 1. To calculate logarithmic UPCh with the single resonant circuits of receiver radars, if are assigned the following technical specifications:

passband UPCh in linear conditions $\Delta F = 1$ MHz;

resonance frequency UPCh $f_0 = 30$ MHz;

the minimum entry stress UPCh of $U_{BX_{MIN}} = 20$ μV ;

the minimum output potential UPCh, caused by receiver noise,

$$U_{BUX_{MIN}} = 0.5 \div 0.7 \text{ V};$$

operating range LAX, amplifier must be not less than 80 dB;

dynamic range on output/yield UPCh relative to the minimum stress of $U_{BUX_{MIN}}$ it must not exceed $h_{00} \leq 12$ dB or $h \leq 4$;

in amplifier stages is applied the tube of the type of 6J5P a by

the pemshremi: $S = 9 \text{ mA/V}$; $C_{BX} = 10 \text{ pF}$; $C_{BLX} = 2,5 \text{ pF}$;
 $C_{npox} = 0,04 \text{ pF}$.

The calculation of logarithmic UPCh is produced by the procedure outlined above.

1. The type of tube is assigned according to technical specifications.

2. According to formula (VI-2) we determine the stress of the U_{BXH} , by which must begin the LAX ray/beam,

$$U_{BXH} = \frac{U_{mBX}}{10} = \frac{U_{BXHMH}}{10} = \frac{20 \cdot 10^{-6}}{10} = 2 \cdot 10^{-6} \text{ a.}$$

3. Being given value of $m = 4$, according to formula (VI-4) we determine the maximum factor of amplification UPCh

$$K_0 = m \cdot \frac{U_{BLXMH}}{U_{mBX}} = \frac{(0,5 \div 0,7) 4}{2 \cdot 10^{-6}} = (1 \div 1,4) 10^5.$$

We take $K_0 = 10^5$.

4. According to formula (VI-5) we determine the maximum factor of amplification of one cascade/stage

$$K_1 = (0,7 \div 0,8) K_{1yct} = (0,7 \div 0,8) 14,5 = 10,1 \div 11,6,$$

where according to [24]

$$K_{1yct} = 0,42 \sqrt{\frac{S}{mC_{npox}}} = 0,42 \sqrt{\frac{9 \cdot 10^{-3}}{2\pi \cdot 30 \cdot 10^6 \cdot 0,04 \cdot 10^{-12}}} = 14,5.$$

We take $K_1 = 10$.

5. We determine the total resistance of the plate load

$$R_0 = \frac{K_1}{S} = \frac{10}{9 \cdot 10^{-3}} = 1,1 \cdot 10^3 \text{ om.}$$

6. According to formula (VI-6) we determine the number of the amplifier stages

$$n = \frac{\ln K_0}{\ln K_1} = \frac{\ln 10^5}{\ln 10} = 5.$$

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7. We determine the passband of one cascade/stage which according to [24] is equal to

$$\Delta F_1 = \Delta F \frac{\sqrt{n+1}}{0,83} = 10^3 \frac{\sqrt{5+1}}{0,83} = 2,95 \text{ Mcu.}$$

In this case it is assumed that the input circuit UPCh also has a passband ΔF_1 . Primamem $\Delta F = 3 \text{ MHz}$.

With this passband the capacitance/capacity of the plate circuit

$$C_0 = \frac{1}{2\pi\Delta F_1 R_0} = \frac{1}{2\pi \cdot 3 \cdot 10^3 \cdot 1,1 \cdot 10^3} = 48 \text{ nph.}$$

8. Is selected the number of nonlinear cascade/stages. If the detector, which stands after UPCh, is carried out on a germanium diode of the type of DG-Q, then it works in linear conditions with input voltage 0.4-0.5 in. Since the minimum output potential UPCh, caused rcises, must be not less than 0.5 in, detector will work in linear conditions in all operating range of IAX LPC regardless of the fact,

will be the last/latter intermediate frequency stage linear or nonlinear. For the expansion of the range of LAX UPCh the last/latter cascade/stage it is expedient also to take nonlinear. In this case the number of nonlinear cascade/stages will be equal the total to number of amplifier stages, i.e., $n_{\text{нел}} = 5$.

9. From expression (VI-8) we determine the coefficient

$$a = \frac{h-1}{n \ln D_1 - h \ln 10} = \frac{4-1}{5 \ln 10 - 4 \ln 10} = 1.3.$$

We take $a = 1$. Since the taken value of coefficient than less required in calculation $a = 1.3$, dynamic range UPCh on output voltage will be obtained than somewhat less assigned. Furthermore, with $a = 1$ calculation n = cascade UPCh from LAX is simplified, since all nonlinear cascade/stages must have identical amplitude characteristics.

10. According to formula (VI-9) we determine entry stress of the last/latter nonlinear cascade/stage by which begins its LAX,

$$U_{\text{вх1}} = U_{\text{вхн}} K_1^{n-1} = 2 \cdot 10^{-2} \cdot 10^4 = 2 \cdot 10^{-2} \text{ в.}$$

11. According to equalities (VI-11) and (VI-12) we determine the stress:

$$U_{\text{вх1}} = U_{\text{вхн}} K_1 = 2 \cdot 10^{-2} \cdot 10 = 0.2 \text{ в.}$$

$$U_{\text{вх1}} = K_1 U_{\text{вхн}} (\ln D_1 + 1) = 0.2 [\ln 10 + 1] = 0.66 \text{ в.}$$

12. According to formula I-62) for output voltages from

$$U_{\text{вх1}} = 0.2 \quad \text{v of up to} \quad U_{\text{вхн}} = 0.66 \text{ в} \quad \text{we design and plot a curve}$$

$$R_{\text{нел1}} = f(U_{\text{нелс}}) \quad (\text{in Fig. 138 dash krivayaz}).$$

13. According to formula (I-64) for output voltages from

$$U_{\text{max}} = 0,66 \quad \text{v of up to}$$

$$U_{\text{max}} = K_1 U_{\text{BX}_1} (i \ln D_1 + 1) = 10 \cdot 2 \cdot 10^{-5} (5 \ln 10 + 1) = 2,5 \text{ V}$$

we design and

construct for the last/latter nonlinear cascade/stage the curved

$$R_{\text{ne}\pi_{111}} = f(U_{\text{ne}\pi_c}), \quad \text{which is the continuation of the curve of}$$

$$R_{\text{ne}\pi_{11}} = f(U_{\text{ne}\pi_c}) \quad \text{and is depicted on Fig. as 138 broken line.}$$

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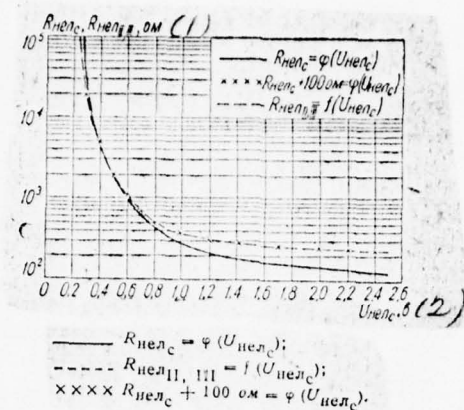


Fig. 138. Curved changes in the resistor/resistance of the nonlinear cell/element:

Key: (1). ohm. (2). \checkmark .

Table 3.

i	1	2	3	4
$U_{нел} (1)$	0,66	1,12	1,58	2,04

Key: (1). \checkmark .

Curved $R_{\text{нел II, III}}$ for remaining nonlinear cascade/stages will accurately the same, but shorter terminate with the voltages of the $U_{\text{вых}}$, which are shown in Table 3.

14. As the nonlinear cell/element, which shunts the plate load of cascade/stage, is selected a germanium diode of the type of D2J.

15. From the method five ordinates we design curved $R_{\text{нел c}} = \varphi(U_{\text{нел c}})$. Calculated curves for different cutoff voltages on diodes are depicted as solid lines on Fig. 40. From this figure it is evident that the curve of the required law of a change in the resistor/resistance of the nonlinear cell/element of $R_{\text{нел II, III}} = f(U_{\text{нел c}})$ coincides sufficiently well with the curve of a true change of the resistor/resistance of nonlinear cell/element $R_{\text{нел c}} = \varphi(U_{\text{нел c}})$ when $E_{\text{зап нел}} = 0,25$ in the range of stresses 0.25-0.8 in, and then these curves diverge. The disagreement of curves it is possible to remove, by connecting in series with nonlinear by cell/element the supplementary linear resistor/resistance of the $R_{\text{доб}} = 100$ ohm, which it is equal to a difference in the resistor/resistances of $R_{\text{нел II, III}} = 218$ ohm and $R_{\text{нел c}} = 100$ ohm with of $E_{\text{зап нел}} = 0,25$ v at the point of $U_{\text{нел c}} = 2,5$ V.

The supplementary resistor/resistances of $R_{\text{доб}}$ for different nonlinear cascade/stages it is expedient to undertake different. The values of these resistor/resistances it is necessary to find as difference in the resistor/resistances of $R_{\text{нел II, III}}$ and $R_{\text{нел c}}$ found through the curves of $R_{\text{нел II, III}} = f(U_{\text{нел c}})$ and $R_{\text{нел c}} = \varphi(U_{\text{нел c}})$ with the stresses of $U_{\text{нел c}}$ corresponding to

the end/lead of the LAX of amplifier and given in Table 3. The values of supplementary resistor/resistances, found in a indicated manner, are brought in Table 4, from which it is evident that for the first nonlinear cascade/stage the resistor/resistance of $R_{R06} = \pm 0$, and for remaining nonlinear cascade/stages it virtually one and the same.

Table 4.

i	1	2	3	4	5
$R_{\text{доб. ом}}^{(1)}$	0	87	90	94	100

Key: (1). ohm.

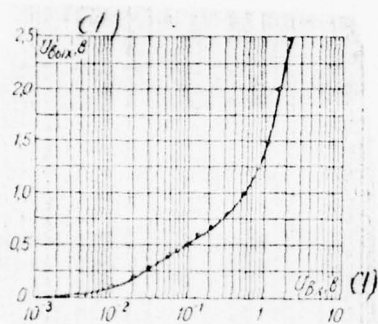


Fig. 139. Calculated and real amplitude characteristics of the fifth cascade/stage of logarithmic amplifier.

Key: (1). V.

Figure 138 by crosses shows the points of the passage of the curve of a change in the resistor/resistance of nonlinear cell/element with series-connected supplementary soprotivleniye $R_{доб} = 100$ ohm. The points of the curve $(R_{нел_с} + 100$ ohm) of $\varphi(U_{нел_с})$ coincide sufficiently well with the required curved $R_{нел_{II, III}} = f(U_{нел_с})$ in all range of the output voltage of the last/latter nonlinear cascade/stage.

Dobavonye resistor/resistances it is expedient to utilize for producing on them the voltages of $E_{зад_{нел}}$, which lock nonlinear cell/elements.

16. From formulas (II-1), (II-2) and (II-4) we design the required amplitude characteristic of nonlinear cascade/stage (unbroken curve in Fig. 139).

According to formula (II-54) with the use of a curve $(R_{нел_с} + 100$ ohm) $\varphi(U_{нел_с})$ we design the real amplitude characteristic of the last/latter (the fifth) nonlinear cascade/stage. The calculation points of real amplitude characteristic are plotted/applied in Fig. 139 and coincide sufficiently well with the required characteristic. For remaining nonlinear cascade/stages real amplitude characteristics will have the same or even lesser deviations from the required characteristic, since curved $(R_{нел_с} + R_{доб}) = \varphi(U_{нел_с})$ for these cascade/stages will be more accurately it sovpadet from the required curved $R_{нел_{II, III}} = f(U_{нел_с})$. Therefore for the calculation of the common amplitude characteristic

of amplifier it is possible to utilize an amplitude characteristic only of last/latter nonlinear cascade/stage.

17. From formula (I-17) we design a precise (ideal) LAX UPCh (broken line in Fig. 140).

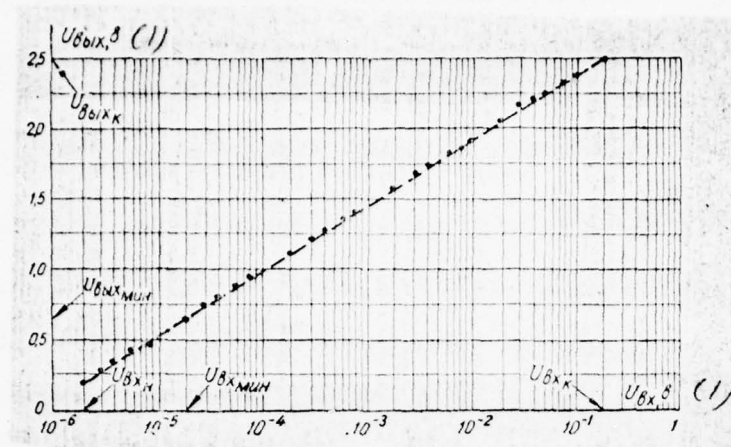


Fig. 140. Calculated and real amplitude characteristics of five-stage logarithmic tuned amplifier.

Key: (1). \checkmark .

On the points of the real amplitude characteristics of nonlinear cascade/stages (in particular according to the amplitude characteristic of the fifth nonlinear cascade/stage, depicted on Fig. 139) we design and construct real logarithmic amplitude characteristic UPCh, that consists of five nonlinear cascade/stages (point in Fig. 140). From the figure one can see that the amplitude characteristic in all logarithmic range 100 dB differs from accurately logarithmic not more than to 3-40/o. This accuracy is completely sufficient for early-warning radar. According to the calculated amplitude characteristic we determine:

overall range LAX UPCh on the input voltage

$$D = \frac{U_{\text{BXK}}}{U_{\text{BXH}}} = \frac{0,2}{2 \cdot 10^{-6}} = 10^5,$$

or

$$D = 100 \frac{(t)}{\text{dB}} \quad (t) \text{ dB}$$

working dipazon LAX UPCh on the input voltage

$$D_{\text{pa6}} = \frac{U_{\text{BX}}}{U_{\text{BXMIN}}} = \frac{0,2}{2 \cdot 10^{-5}} = 10^4,$$

or $D_{\text{pa6}} = 80$ dB, i.e., it corresponds that which was assigned; dynamic range on the output voltage

$$h = \frac{U_{\text{BXK}}}{U_{\text{BXMIN}}} = \frac{2,5}{0,66} = 3,8,$$

or $h = 11.6$ dB, i.e., less assigned $h = 12$ dB.

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With dynamic range on output voltage 12 dB, there is no need for for the application/use of a limiter after detector. In the absence of the limiter of mark on an indicator of the type "b "(with brightness indication) from the objects, arrange/located at different distances, they have different brightness. Furthermore, the marks from the closely locating ground features are always brighter, than mark from objects, that considerably oblagchaet the discrimination of objects against the background of interferences from the ground features. Conditions of observation of object on the screen of the type "b ", at output/yield of the logarithmic receiver confronting without limiter, considerably better/best, than on the indicator, connected at the output/yield of linear-receiver with limiter.

18. From Table 3 we find the maximum entry stress of the last/latter (fifth) nonlinear cascade/stage (it the output voltage of the fourth nonlinear cascade/stage) at the end of the LAX UPCh of $U_{\text{BX}(5) \text{ MAX}} = 2 \text{ V}$. With output voltage 2 in the amplifier tube of the fifth cascade/stage works without overloading.

Thus, the calculated logarithmic amplitude characteristic UPCh satisfies zadany requirements.

19. According to the transient responses, depicted on Fig. 122 and given in work [11], we determine the maximum relative change of

the time lag of signal in logarithmic UPCh

$$\Delta \alpha_{3\text{max}} = 2,45.$$

In this case, the maximum absolute change in the time lag of the signal

$$\Delta t_{3\text{max}} = \Delta \alpha_{3\text{max}} \cdot 2R_0C_0 = 2,45 \cdot 2 \cdot 1,1 \cdot 10^3 \cdot 48 \cdot 10^{-2} = 2,6 \cdot 10^{-7} \text{ сек. (1)}$$

(1)
s.

20. We determine the maximum supplementary error in ranging, caused by application/use in receiver radars UPCh with logarithmic amplitude characteristic,

$$\Delta d_{\text{max}} = 150 \Delta t_{3\text{max}} = 150 \cdot 0,26 = 39 \text{ m. (1)}$$

(1)
m.

This supplementary error in ranging is completely permissible for a receiver early-warning radar.

Example 2. To calculate logarithmic video amplifier with nonlinear feedback from the following technical specifications:

the maximum factor of amplification of video amplifier $K_0 = 10^4$;

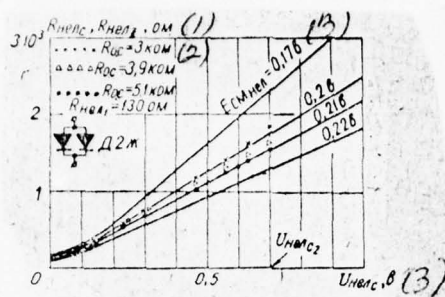
the set-up time of momentum/impulse/pulse in the work of video amplifier in linear conditions must be equally of $t_y \leq 0,3 \mu\text{s}$;

range the LAX of video amplifier on input voltage must be not

less than 75-80 dB;

output potential of the amplifier with which begins LAX, the

$$U_{\text{max}} = 0,5 \div 1,0 \text{ V.}$$



Key: (1). ohm. (2). k ohm, (3). V.

relative overshoot toward the end of the LAX of amplifier must not exceed 5-100/o.

The calculation of logarithmic video amplifier is produced by the procedure presented.

1. Is selected the diagram of video amplifier with nonlinear cell/elements in the cathode circuits of amplifier stages, since it is required to ensure sufficiently high accuracy LAX over a wide range and small parasitic overshoot.

2. Is selected a tube of the type "6J5P".

3. We determine the output voltage by which must begin the LAX of video amplifier, assuming that will be provided for the successive work of nonlinear cascade/stages and is obtained range LAX, equal to factor of amplification

$$U_{BXH} = \frac{U_{BHXH}}{K_0} = \frac{0,5 \div 1}{10^4} = (5 \div 10) 10^{-5} \text{ V}$$

We take

$$U_{BXH} \approx 7,5 \cdot 10^{-5} \text{ V}$$

4. We are assigned by the number of nonlinear cascade/stages $n = 3$.

5. We determine the required maximum factor of amplification of one cascade/stage

$$K_1 = \sqrt[3]{K_0} = 21,6.$$

For providing a successive work of nonlinear cascade/stages, it is necessary to fulfill the equality

$$K_1 = D_1 = 21,6.$$

6. Since the video amplifier must logarithmize video pulses according to the law of natural logarithm, coefficient $a = 1$.

7. We determine the input voltage by which must begin the LAX of the nonlinear cascade/stage

$$U_{bx1} = K_1^{n-1} U_{bxH} = 21,6^2 \cdot 7,5 \cdot 10^{-5} = 35 \cdot 10^{-3} \text{ V.}$$

8. For this amplifier as nonlinear cell/element, is selected a germanium diode of the type of D2J. In order that nonlinear cell/element would have comparatively small initial resistor/resistances of $R_{\text{нел}}$, we include in parallel two diode.

9. According to the procedure, presented in §5 chapter II, we design and construct the family of curves of $R_{\text{нел}} = \varphi(U_{\text{нел}})$ for different bias voltages on nonlinear cell/element (solid line in Fig. 141). Under nonlinear cell/element in this case, we will understand the pair of the in parallel connected diodes D2J.

Table 5.

$E_{\text{снел}}^{(1)}$	0,1	0,13	0,15	0,17	0,20	0,21	0,22	0,25
$R_{\text{нел}}^{(2)}$	830	320	270	200	140	130	110	70

Key: (1). ✓. (2). ohm.

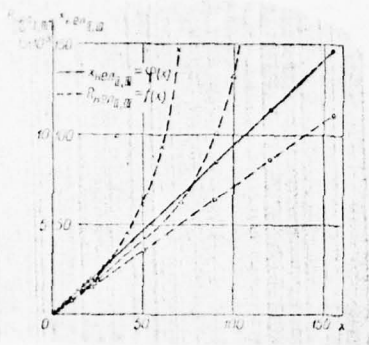


Fig. 142. Calculated curve $R_{\text{нел}, \text{III}} = f(x)$ and $x_{\text{нел}, \text{III}} = \varphi(x)$ for a cascade/stage with nonlinear current feedback.

In Table 5 are brought the initial values (minimum values) of the resistor/resistance of nonlinear cell/element with different bias voltages $E_{cm_{нел}}$ on it.

10. From formulas (II-78) and (II-80) we design and construct the dependences of $R_{нелII} = f(x)$ and $x_{нелII} = \varphi(x)$ for the relative input voltage $x = (1-D_1) = (1-21.6)$, from formulas (II-83) and (II-84) we design and construct the dependences of $R_{нелIII} = f(x)$ and $x_{нелIII} = \varphi(x)$ for $x = D_1 - D_1 [(i-1) \ln D_1 + 1] = 21.6 - 21.6 [(3-1) \ln 21.6 + 1] = 21.6 - 154$. Value $x = 21.6 - 156$ are accepted for the last/latter, third nonlinear cascade/stage. For it $i = 3$. Since in this case of $a = 1$, the curved $R_{нелII, III} = f(x)$ and $x_{нелII, III} = \varphi(x)$ are identical for all nonlinear cascade/stages, differing only in terms of range x . The carried out complete crew of nonlinear cascade/stage at two values of the resistor/resistance of $R_{нелI} = 70$ and 130 ohm showed that the best results are obtained with $R_{нелI} = 130$ ohm.

Calculated curve $R_{нелII, III} = f(x)$ and $x_{нелII, III} = \varphi(x)$ for an $R_{нелI} = 130$ ohm and three values of the resistor/resistance of $R_{o.c}$ are depicted on Fig. 142. The curved $x_{нелII, III} = \varphi(x)$ with of $R_{нелI} \leq (100 \div 150)$ ohm and the $R_{o.c} \geq 3 \text{ КОМ}$ in practice does not depend on the value of the resistor/resistance of $R_{o.c}$.

11. Taking into account that $U_{нелc} = U_{вх} x_{нелII, III}$ on the curves of $R_{нелII, III} = f(x)$ и $x_{нелII, III} = \varphi(x)$ for the selected value of $R_{нелI} = 130$ ohm, that it corresponds to bias voltage on the nonlinear

cell/element of $E_{cm, \text{нел}} = 0,21 \text{ V}$ and for the different values of the resistor/resistance of $R_{o, c}$ we design and we plot a curve

$R_{\text{нел II, III}} = f(U_{\text{нел c}})$ on one curve/graph with the curves of $R_{\text{нел c}} = \varphi(U_{\text{нел c}})$.

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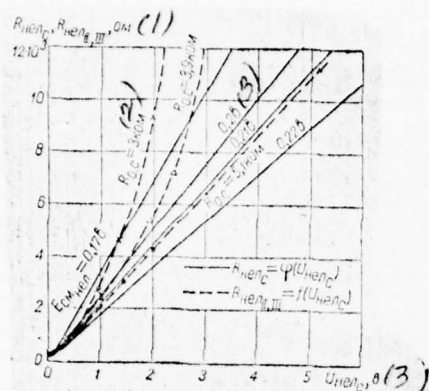


Fig. 143. Calculated curve $R_{\text{нел c}} = \varphi(U_{\text{нел c}})$ and $R_{\text{нел II, III}} = f(U_{\text{нел c}})$ for a cascade/stage with nonlinear current feedback.

Key: (1). ohm. (2). *Kahn* (3). \checkmark .

The calculation points for the logarithmic section of the amplitude characteristic of cascade/stage, that corresponds to $x = (1-21.6)$ or the $U_{\text{нелс}} = 1.8 \cdot 10^{-2} \div 0.7$ V into in $U_{\text{вх1}} = 3.5$ mV, are plotted/applied in Fig. 142. For the resistor/resistance of the $R_{0.c} = 3$ ком these points are shown by crosses, for the $R_{0.c} = 3.9$ ком - by triangles, for the $R_{0.c} = 5.1$ ком - by circles. The calculation points of the curves of $R_{\text{нелII, III}} = f(U_{\text{нелс}})$, connected with broken line, for the quasi-linear section of the amplitude characteristic of the last/latter, third nonlinear cascade/stage at the same values of the resistor/resistance of $R_{0.c}$ are shown in Fig. 143.

Curved $R_{\text{нелII, III}} = f(U_{\text{нелс}})$ are suitable also for the second and first nonlinear cascade/stages. For the third nonlinear cascade/stage curved $R_{\text{нелII, III}}$ are utilized completely with $U_{\text{нелс}} = 1.8 \cdot 10^{-2} \div 5.1$ V, which corresponds to $x = (1 - 154)$; for the second - in $U_{\text{нелс}} = 1.8 \cdot 10^{-2} \div 2.96$ V that corresponds to $x = 1-88$; for the first - with $U_{\text{нелс}} =$ which corresponds to $x = 1-21.6$.

Figure 143 shows that the best agreement of the curve of the $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ with of $E_{\text{смнел}} = 0.21$ V with the required law of a change in the resistor/resistance of the nonlinear cell/element of $R_{\text{нелII, III}} = f(U_{\text{нелс}})$ is obtained during the resistor/resistance of the $R_{0.c} = 5.1$ ком.

12. We design total resistance in the anode circuit of nonlinear cascade/stage. From formula (1-77) we obtain

$$R_0 = \frac{K_1 (1 + S\rho_1)}{S} = \frac{21,6 (1 + 9 \cdot 10^{-3} \cdot 127)}{9 \cdot 10^{-3}} = 5,14 \text{ КОМ},$$

where

$$\rho_1 = \frac{R_{0.c} R_{\text{нел}_1}}{R_{0.c} + R_{\text{нел}_1}} = \frac{5,1 \cdot 10^3 \cdot 130}{5,1 \cdot 10^3 + 130} = 127 \text{ Ом}.$$

Upon the inclusion into the anode circuits of the cascade/stages, which cut the reverse/inverse overshoots of semiconductor diodes, resistor/resistance R_0 determines from the expression

$$\frac{1}{R_0} = \frac{1}{R_{\text{вдх}}} + \frac{1}{R_{\text{вх}}} + \frac{1}{R_{\text{а}}} + \frac{1}{R_{\text{нел}}},$$

where the $R_{\text{нел}} = (10 \div 15) \text{ КОМ}$ - the back resistance of the cutting semiconductor diodes for low signals.

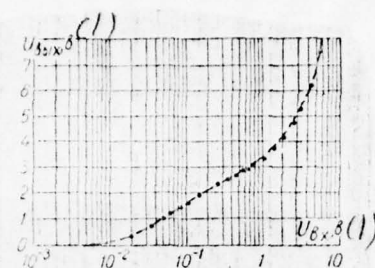


Fig. 144. Calculated and real amplitude characteristics of cascade/stage with nonlinear current feedback.

Key: (1) - ∇ .

13. From the curve of the $R_{\text{нелс}} = \varphi(U_{\text{нелс}})$ with of $E_{\text{нелс}} = 0,21$ v and formulas (II-73) and (II-76) we design and construct the real amplitude characteristic of the last/latter nonlinear cascade (it is marked by crosses in Fig. 144).

Figure 144 shows that the real amplitude characteristic of cascade/stage differs from the required characteristic (dashed curve) to the side of great significance in the beginning of logarithmic section and to the side of smaller values on quasi-linear section. These divergences in n-cascade amplifier must largely compensate for.

14. From the real amplitude characteristic of nonlinear cascade/stage, we design and construct the real amplitude characteristic of three-stage video amplifier. The calculation points, together with precise by LAX (dash straight line), are depicted on Fig. 145, from which it is evident that the calculated amplifier has real logarithmic amplitude characteristic in the range (on input voltage) 80 dB. The divergence of real amplitude characteristic from accurately logarithmic in all range 80 dB does not exceed 30/o.

15. We design the set-up time of momentum/impulse/pulse in the work of video amplifier in linear conditions. Set-up time of momentum/impulse/pulse at the output/yield of one linear cascade/stage

$$t_{y1} = 2C_0 R_0 = 2 \cdot 13 \cdot 10^{-12} \cdot 5,1 \cdot 10^8 = 1,3 \cdot 10^{-7} \text{ s}$$

where

$$C_0 = C_{bHX} + C'_{bX} + C_M = 2,5 + 4,66 + 6 \approx 13 \text{ pF.}$$

In the presence of negative current feedback the dynamic input capacitance of the tube

$$C'_{bX} = \frac{C_{bX}}{1 + S\beta}.$$

In the work of nonlinear cascade/stage in linear conditions, we obtain

$$C'_{bX} = \frac{C_{bX}}{1 + S\beta_1} = \frac{10}{1 + 9 \cdot 10^{-8} \cdot 127} = 4,66 \text{ pF.}$$

In view of the fact that all nonlinear cascade/stages identical, the set-up time of momentum/impulse/pulse at the output/yield of video amplifier in work in the linear conditions

$$t_y = t_{y1} \sqrt{n} = 1,3 \cdot 10^{-7} \sqrt{3} = 2,3 \cdot 10^{-7} \text{ s.}$$

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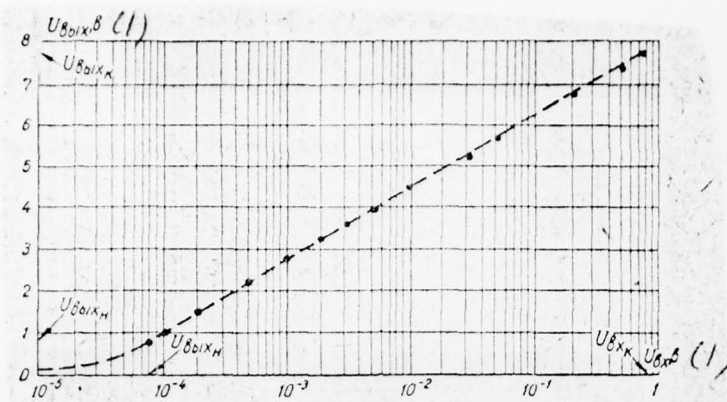


Fig. 145. Calculated and real amplitude characteristics of three-stage logarithmic video amplifier.

Key: (1). \checkmark

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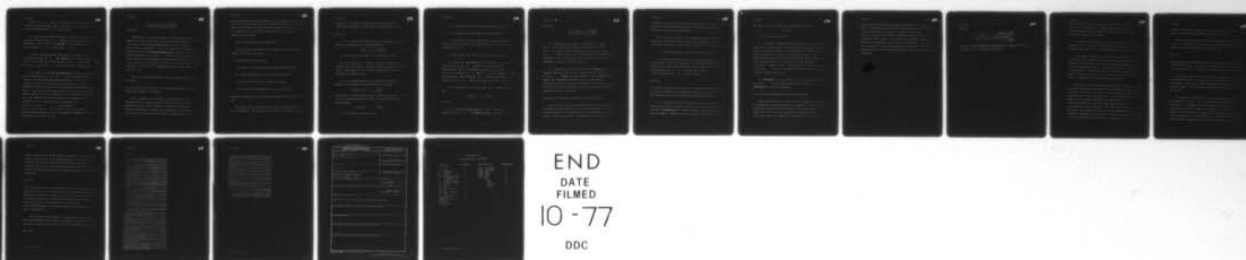
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Thus, time of t_y does not exceed that which was assigned in technical specifications. With an increase in the input time signal, of the establishment of t_y will decrease.

16. From formula (V-59) we design the relative overshoots of the nonlinear cascade/stages of d_k for the end/lead of the LAX of amplifier. For the first cascade/stage this corresponds to $x = 21.6$; for the second - $x = 88$, for the third - $x = 154$.

On curve, depicted on Fig. 143, we find the values of the resistor/resistance of $R_{\text{нелс}}$ and substitute in formula (V-59). Then for the first nonlinear cascade/stage we obtain $d_{k(1)} = 1,34 \cdot 10^{-4}\%$; for the second $d_{k(2)} = 6,5 \cdot 10^{-5}\%$ and for the third $-d_{k(3)} = 4,3 \cdot 10^{-5}\%$.

In the work of nonlinear cascade/stages in linear conditions for all cascade/stages of $d_k = 1,38 \cdot 10^{-4}\%$. If the network elements of nonlinear cascade/stages are selected from the condition of the equality of sum (V-21) to zero in the beginning of the LAX of amplifier [network elements of the nonlinear cascade/stage of C_ϕ, C_s and C_c are located from expressions (V-15), (V-16) and (V-17)], then at the end the LAX of amplifier in each nonlinear cascade/stage will occur certain the perekorreksiya of the reverse/inverse overshoot: in the first nonlinear cascade/stage of

$$d_{n(1)} = d_k - d_{k(1)} = 0,4 \cdot 10^{-5}\%; \quad \text{in the second -}$$

$$-d_{n(2)} = d_k - d_{k(2)} = 7,3 \cdot 10^{-5}\%; \quad \checkmark \quad \text{in the third - } d_{n(3)} = d_k - d_{k(3)} = 9,5 \cdot 10^{-5}\%.$$

General perekorreksiya at the output/yield of logarithmic video amplifier at the end of the LAX

$$d_n = d_{n(1)} K_1^2 + d_{n(2)} K_1 + d_{n(3)} = 4 \cdot 10^{-6} \cdot 21,6^2 + \\ + 7,3 \cdot 10^{-6} \cdot 21,6 + 9,5 \cdot 10^{-6} = 2,51 \cdot 10^{-3} \%$$

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Calculate of the perekorreksiya of reverse/inverse overshoot is observed at the output/yield of logarithmic video amplifier, if to input enter ideal momentum/impulse/pulses without parasitic reverse/inverse overshoots. If for the input of the designed video amplifier enter real momentum/impulse/pulses with the parasitic relative overshoot of $d_{ax} = 0,01\%$, then upon the inclusion into the anode circuits of the nonlinear cascade/stages of the cutting diodes of the type DG-Q or D2 relative overshoot at the output/yield of video amplifier at the end of the logarithmic range does not exceed 20/o (see Fig. 126).

Thus, the calculated logarithmic video amplifier satisfies all specified.

§2. Procedure for calculation of logarithmic amplifiers during the consecutive addition of voltages.

LAX is obtained by the addition of the voltages from the output/yields of cascade/stages most frequently in the selective amplifiers of radio pulses (method of consecutive detection). Therefore calculation procedure for calculation in obtaining LAX by this method it is expedient to examine in connection with the

selective amplifiers of radio pulses. All the skhemye solutions of this method (diagram with separate detectors, diagrams with cathode, anode and grid detection) are designed from single procedure. During the calculation of logarithmic amplifier, must be assigned the following initial data:

the resonance frequency of amplifier f_0 ;

the factor of amplification K_0 and passband ΔF of the work of amplifier in linear conditions;

range LAX in input voltage D ;

range LAX in the output voltage of D_{max} or coefficient a .

One should distinguish two case of the calculation:

- 1) tentative calculation of amplifier from LAX;
- 2) the calculation of amplifier with precise by LAX.

Tentative calculation of the selective amplifier of radio pulses from LAX.

We assume that all cascade/stages work in linear conditions up to their overloading. The procedure for tentative calculation let us

examine in an example of diagram with separate detectors. The calculation of amplifier is produced in the following order.

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1. On the basis of formula (II-40) we determine the required factor of amplification of one cascade/stage

$$K_1 = e^{\frac{1}{a}}. \quad (\text{VI-13})$$

2. We determine the number of the amplifier stages:

a) if is assigned the common/general/total coefficient of amplifier K_0 , the number of cascade/stages is determined from formula (VI-6). Then dynamic range the LAX of amplifier is determined according to formula (II-37);

b) if is assigned dynamic range the LAX of amplifier D , the number of cascade/stages we determine from the formula

$$n = \frac{\ln D}{\ln N} + 1 = \frac{\ln D}{\ln K_1} + 1, \quad (\text{VI-14})$$

which easy to obtain from expressions (II-37) and (II-40). In this case the common/general/total factor of amplification of the cascade/stage

$$K_0 = K_1^n = N^n. \quad (\text{VI-15})$$

3. Is selected the type of tube.

4. We determine the passband of one cascade/stage ΔF_1 .
5. We design the cell/elements of amplifier stage.
6. We design the detector, connected at the output/yield of amplifier stage, according to the procedure, presented in A. P. Sievers' book [25].
7. From formulas (IV-29) or (V-70) we design delay line.
8. According to the characteristics of tube, we determine the input voltage of the U'_{bx} , by which is impregnated the cascade/stage, and the respectively output voltage of U'_{bix} . The values of the voltages of U'_{bx} and U'_{bix} it is expedient to refine experimentally. The voltage of U'_{bix} is output potential of the amplifier of the U_{bixH} , with which begins the LAX of amplifier.
9. We determine entry stress of the U_{bxH} , by which begins the LAX,

$$U_{bxH} = \frac{U_{bixH}}{K_1^n}. \quad (VI-16)$$

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10. We determine entry stress of U_{bxK} and on the output/yield of the U_{bixK} , by which terminates the LAX of the

amplifier:

$$U_{BXK} = K_1^{n-1} U_{BXH}; \quad (VI-17)$$

$$U_{BXK} = nK_1^n U_{BXH}. \quad (VI-18)$$

11. Multiplying the values of the stresses of U_{BXH} and U_{BXK} on the transmission factors of the detector of k_d and line of k_p , we find the values of the vidoc voltages of $U_{BXH, D}$ and $U_{BXK, D}$ removed from the load of delay line with which begins and terminates the LAX of amplifier. The transmission factor of k_p is determined according to formula (IV-33).

12. Graphically we construct the LAX of amplifier, connecting by straight line two points with the coordinates of U_{BXH} , $U_{BXH, D}$ and U_{BXK} , $U_{BXK, D}$ nanosennye with reference grid on semilogarithmic scale. The constructed straight line will approximately reflect/represent the real LAX of amplifier. The allowed error can be determined by curve, depicted on Fig. 17, by knowing the factor of amplification of cascade/stage.

Calculation of selective amplifier with precise by LAX.

With the method of the consecutive addition of stresses, the amplifier has a precise LAX only in such a case, when the amplitude characteristics of its cascade/stages are described by expressions (II-47), (II-49) and (II-51). Consequently, as a result of the

calculation it is necessary to attain this position in order that the calculated cascade/stages would have the amplitude characteristics, described by the indicated equations.

The calculation procedure for calculation let us examine in connection with diagrams with cathode, anode and grid detection. Logarithmic amplifier in this case is designed in the following order.

1. Is selected amplifier circuit and the type of tube.
2. We design the dependences of fundamental harmonic and the feed current of tube on the amplitude of the input voltage during the different operating modes of tube and at the different values of the resistor/resistance of R_k in the cathode circuit or resistor/resistance of R_g in grid circuit.

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Is selected that curve of a change in the fundamental harmonic which has the sufficiently large logarithmic section of poryadk 18-20 dB, and sharp knee after having emerged from logarithmic section.

3. Is selected the total resistance of the plate load of cascade/stage in such a way that taking into account by-passing the subsequent cascade/stage the maximum factor of amplification of cascade/stage K'_i would be on unity less than the dynamic range of

its LAX, i.e., must be fulfilled the following equality:

$$K'_1 = D_1 - 1.$$

4. We design delay line.

5. We design the amplitude characteristics of cascade/stage from radio- and to video voltage. Characteristic on radio-voltage must be similar to curve, described by equations (II-47), (II-49) and (II-51), while characteristic on video voltage must be linear. From these characteristics we design the characteristics of cascade/stages from video voltage depending on entry stress of the amplifier of

$U_{BUXB} = f(U_{BXY})$ (see Fig. 103). In its form of the characteristic of
 $U_{BUXB} = f(U_{BXY})$ they must coincide with curved, described expressions (II-46), (II-50) and (II-52).

6. Store/adding up the ordinates of the characteristics of the
 $U_{BUXB} = f(U_{BX})$ of all cascade/stages, we construct the
 characteristic of entire amplifier.

§3. Tuning of IZIRATEL*NOGO logarithmic amplifier.

After calculating the network elements of logarithmic amplifier, is collect/built mock-up and begin its adjustment. The adjustment of logarithmic amplifier one should carry out into two stages. In the first stage it is necessary amplifier to regulate in linear conditions. After the amplifier is controlled in linear conditions

(are obtained the necessary parameters of amplifier - the maximum factor of amplification K_0 , passband ΔF and resonance frequency f_0), begin the adjustment of amplifier in work in logarithmic mode/conditions for the purpose of obtaining precise by LAX in the calculated dynamic range. The adjustment of amplifier begins with the adjustment of separately each nonlinear cascade/stage. In this case, it is necessary to attain this position in order that the amplitude characteristics of nonlinear cascade/stages would correspond precisely calculated.

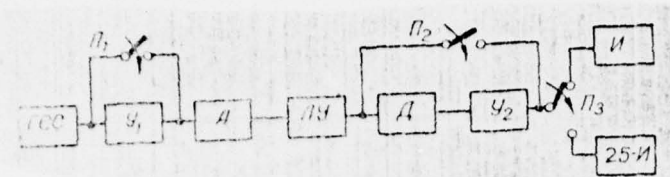


Fig. 146. Block diagram of installation for taking the amplitude characteristic of logarithmic amplifier.

only in this case possible sufficiently easily and rapidly to obtain a precise LAX of amplifier as a whole. After are controlled all nonlinear cascade/stages, they begin the adjustment of entire logarithmic amplifier as a whole.

The amplitude characteristic of both of separate selective nonlinear cascade/stage and entire amplifier as a whole can be removed sufficiently accurately on the block diagram, depicted on Fig. 146.

As the source of signal, can be used high-stability standard signal generator (standard signal generator), from output/yield of which can be remove/taken both usual sinusoidal vykhokachastotnye oscillation/vibrations and the oscillation/vibrations, modulated in pulse amplitude or audio frequency. The fundamental requirement, imposed to signal generator, is the high stability of amplitude and depth of modulation of the generatable oscillations.

The amplitude of the oscillations, removed with standard signal generator, can fall short; therefore after signal generator necessary to switch on amplifier U_1 with the strictly constant coefficient of amplification in time. The value of the signal, which enters the input of the adjustable amplifier from LAX (LU), can be establish/installed by the attenuator, which stands at the output/yield of signal generator. But since the attenuators of signal generators frequently have large error in calibration, for taking the amplitude characteristic of amplifier with the high accuracy necessary of mezhdu by amplifier U_1 and tuned LU to switch on the supplementary

broadband attenuator A, which makes it possible with high accuracy to change attenuation within limits from 0 to 100-120 dB.

For the accuracy of taking the LAX of amplifier, it is necessary that by the attenuator it was possible to change attenuation abruptly through 2-5 dB with accuracy not less than 1c/o.

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The diagram and the construction of this attenuator is described in the literature [14]. When using a supplementary precise attenuator, the attenuation in the attenuator of signal generator reduces to zero.

As measuring meter and, the connected at output/yield selective logarithmic amplifier, can be used the cathode voltmeter of high class of accuracy. During rough taking amplitude characteristic as measuring meter, can be used the oscillograph of the type of 25I or S1-8 (UO-1M).

The amplitude characteristic of cascade/stage or amplifier is remove/taken as follows. In the output/yield of standard signal generator, is establish/installed the maximum stress, and in attenuator A, introduce complete attenuation. If output voltage standard signal generators is small, then is connected amplifier U₁ (they disconnect/turn off key/wrench P₁). Then, gradually decreasing the attenuation, introduced by attenuator, with the aid of cathode

voltmeter is record/fixed output voltage for each value of the attenuation of attenuator. The attenuation of the attenuator of amplifier will not initiate to enter the signals, which emerge from the dynamic range of the LAX of amplifier. After depositing points to semilog diagram, is obtained the real amplitude characteristic of amplifier, which must be straight line in the case of small divergences from accurately logarithmic amplitude characteristic.

The error in the real amplitude characteristic of amplifier is determined by the deviation of points from straight line. The error in taking the amplitude characteristic of amplifier in this case is determined by the errors, introduced by attenuator, by measuring meter and the subjective errors of operator.

For rapid checking the accuracy of real logarithmic amplitude characteristic, the izbiratel'noto of amplifier can be applied the method, by cited author by the modulated oscillations whose essence entails the following. If we to the input of logarithmic amplifier feed high-frequency oscillations with the amplitude of the U_m , modulated in amplitude by audio frequency with the modulation factor of $m = \frac{U_o}{U_m}$ (U_o — the amplitude envelope audio frequency to the input of amplifier), then at the output of amplifier the amplitude envelope audio frequency

$$U_{2\text{max}} = K_0 U_{\text{max}} a \ln(1 + m) \quad (\text{VI-19})$$

and in the case of $m = \text{const}$ will not depend on the value of the

amplitude of high-frequency oscillation at the input of amplifier in all dynamic range of LAX.

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If output potential of selective amplifier linearly is rectified with the aid of detector d and is isolated envelope of audio frequency, then the amplitude envelope can be accurately measured by cathode voltmeter (amplifier U_2 with coefficient K_2 can be included for an increase in the amplitude detected envelope in the case of the low values m , K_0 and U_{bxH}).

Rapid checking the accuracy of the LAX of selective amplifier is conducted as follows. In standard signal generator, is establish/install the determined modulation factor m . For the more precise determination of the point of the deflection of the objective parameter of amplifier from accurately logarithmic coefficient m undertake not more than 0.02-0.05. In this case the formula (VI-19) assumes the form

$$U_{\varphi_{max}} = amK_0U_{bxH}. \quad (VI-20)$$

Further they change the attenuation of attenuator and control the arrow/pointer of voltmeter. In the case of the register of the objective parameter of amplifier with logarithmic, the arrow/pointer of the voltmeter, connected after amplifier U_2 , is motionless and shows value

$$U'_{\varphi_{max}} = amU_{bxH}K_0K_2 \quad (VI-21)$$

during a change in the entry stress of logarithmic amplifier in all dynamic range of LAX. If the rifleman/gunner of voltmeter at some values of input voltage differs from the value, determined by expression (VI-21), then this indicates the fact that with these input voltage the objective parameter of amplifier differs from accurately logarithmic.

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The throw of the pointer of voltmeter from the assigned magnitude to large side indicates an increase in the slope/transconductance of real amplitude characteristic (decrease in the odnovaniya of logarithm N) in comparison with that which was assigned and, on the contrary, deflection to lesser side indicates a decrease in the slope/transconductance of amplitude characteristic (increase in the base of logarithm N).

By the modulated oscillations it is possible to very rapidly check the amplitude characteristic of amplifier and to determine the sections of characteristic, which differ from accurately logarithmic.

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C535 AVIATION SYS COMD	1	ETID	3
C557 USAIIC	1	NIA/PHS	1
C591 FSTC	5	NICD	5
C619 MIA REDSTONE	1		
D008 NISC	1		
H300 USAICE (USAREUR)	1		
P005 ERDA	2		
P055 CIA/CRS/ADD/SD	1		
NAVORDSTA (50L)	1		
NAVWPNSCEN (Code 121)	1		
NASA/KSI	1		
544 IES/RDPO	1		
AFIT/LD	1		